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THE EFFECT OF TEMPERATURE AND HUMIDITY ON THE ANTISTATIC PROPERTIES OF CONVEYOR BELTING

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THE EFFECT OF TEMPERATURE AND HUMIDITY ON THE ANTISTATIC PROPERTIES
OF CONVEYOR BELTING

by

K.J. Mintz*

ABSTRACT

Polyvinylchloride (PVC) and rubber conveyor belt samples were tested for electrical surface resistance over a wide range of temperatures and humidities. The resistance of PVC beltings was shown to increase sharply with decreasing temperature. An empirical equation was used to fit the data so as to allow extrapolation to the temperature at which the resistance becomes infinite (approximately -25°C). Existing standards on antistatic hazards, which test at a fixed temperature (usually 20°C), are not adequate to identify potentially hazardous materials. The resistance of rubber beltings increase only slightly with decreasing temperature. Humidity does not have a significant effect on the resistance, except at very high humidities. The effect of different electrode arrangements was also studied. The CENELEC method using rectangular electrodes applied with silver paint was found to be superior to the circular brass electrodes with liquid contact agent. An upper limit of 200 M Ω is proposed for the surface resistance measured by the CENELEC method.

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Keywords: static electricity, conveyor belts, underground mines, hazardous locations.

EFFET DE LA TEMPÉRATURE ET DE L'HUMIDITÉ SUR LES PROPRIÉTÉS
ANTISTATIQUES DES COURROIES DE CONVOYEUR

par

K.J. Mintz*

RÉSUMÉ

Des échantillons de courroies à bande en chlorure de polyvinylidène (PVC) et en caoutchouc ont été essayés dans le but d'étudier leur résistivité à la surface électrique. Lors des essais, la résistivité des courroies PVC augmentait rapidement avec une diminution de la température. On s'est servi d'une formule empirique afin d'adapter les données dans le but de permettre une extrapolation de la température à laquelle la résistance devient infinie, soit à environ -25°C . Une température de 20°C est utilisée habituellement au cours des essais qui ont lieu suivant les normes actuelles sur les dangers de l'accumulation d'électricité statique. La résistivité des courroies en caoutchouc augmente quelque peu avec une diminution de la température. L'humidité, sauf à des niveaux très élevés, n'a aucun effet significatif sur la résistivité. Au cours de ces travaux, on a aussi étudié différents arrangements d'électrodes. Enfin, on a réalisé que la méthode CENELEC à l'aide d'électrodes rectangulaires posées avec de la peinture argent était supérieure à la méthode utilisant des électrodes circulaires en laiton avec un agent de contact liquide. Une limite supérieure de 200 Mohm a été proposée pour la résistivité de surface mesurée à l'aide de la méthode CENELEC.

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Mots-clés: électricité statique; courroies de convoyeur; mines souterraines; environnements dangereux.

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INTRODUCTION

In environments containing explosive gases, a spark generated by static electricity may be sufficient to cause a gas/air explosion. In particular, a number of explosions in underground coal mines, which often contain pockets of explosive concentrations of methane, have led many countries to require that nonmetallic materials used therein be made antistatic.

A test for the antistatic characteristic may be made directly by generating a static charge on the test material by rubbing, bombarding with dust, etc. and then determining if the magnitude of the resultant discharge is sufficient to ignite the explosive gas mixture (1,2). Indeed, an international standard has been proposed using one such method (3). However, such methods, although widely used in research studies, have not gained favour for routine evaluations of materials because of their complexity. More commonly, certification authorities rely on an indirect method, the measurement of the electrical surface resistance. In this method, the resistance between electrodes placed on the test surface is measured: the criterion is that the resistance must not exceed a certain fixed value.

A number of different types of electrodes and geometries have been used for measuring the electrical surface resistance (4). The International Standards Association (ISO) has published a standard for conveyor belting (5), which uses concentric brass electrodes (a cylinder of 25 mm diameter and a ring of inner diameter 125 mm and outer diameter 150 mm) with a liquid contact agent made of polyethylene glycol, water and soap. The test conditions are $23 \pm 2^\circ\text{C}$ and $50 \pm 5\%$ R.H. The maximum allowed resistance is 300 M Ω m. This Standard is based closely on the National Coal Board (U.K.) Specification 158/1980 (6). The only significant difference is that the latter tests at $20 \pm 2^\circ\text{C}$ and $65 \pm 5\%$ R.H.

CEAL has been using the ISO/NCB method for measuring the surface resistance of conveyor belting and flexible ventilation materials for about 10 years. This method has been incorporated into the Canadian Standards Association Standard M422, Fire-retardant Conveyor Belting (to be published shortly). For rigid tubing, for which it is impossible to apply the ISO/NCB method, CEAL has been using the electrode arrangement described in CENELEC (European) Standard (7) and the ASTM Standard (4), which was developed for plastics used for explosion-proof electrical enclosures. The electrodes, 1 mm wide, 100 mm

long and 10 mm apart are painted directly on the product under test with silver paint. The specifications in the CENELEC Standard are 1000 Mohm at 23°C and 50% R.H. However, to make the maximum allowed value consistent with the 300 Mohm limit measured by the ISO/NCB method, CEAL selected a limit of 120 Mohm for the former.

A comparison of the ISO/NCB and the CENELEC methods on some conveyor belting and brattice cloth was carried out by Sarin (8). The ratio of the surface resistance (ISO/NCB method) to the surface resistance (CENELEC method) varied from 0.4 to 3.8. This variability was believed to be intrinsic to the difference between the two methods.

The purpose of the present study was to study the difference between the two methods in more detail as well as to study the effects of humidity and temperature. This study was restricted to conveyor belting.

EXPERIMENTAL

The samples were cleaned with distilled water, dried and conditioned for at least 24 h at 20°C and 50% R.H. before testing. Although the ISO/NCB Standard calls for cleaning to be carried out with Fuller's earth, for samples that have grooves or indentations, it is impossible to remove all the Fuller's earth afterwards, as is required.

The recent installation of an environmental chamber permitted variation of the temperature between 0 and 40°C (with about 0.2°C accuracy) and the relative humidity between 10 and 90% (with about 3% accuracy). A small change in conditions required 1-2 h for the surface resistance to come to a constant reading; a large change required up to 4 h.

For the ISO/NCB method, the brass electrodes and the liquid contact agent were the same as specified in those standard. Because the liquid contact agent dried out after an hour or so, it was found necessary to apply fresh liquid contact agent for each measurement. For the CENELEC method, "silver print", manufactured by GC Electronics, was used. It should be noted that it contains butyl acetate as the solvent. The solvent evaporated quickly and did not appear to affect the samples. Masking tape was used to ensure that the boundaries of the electrodes were sharp. Some tests were also carried out with silver-painted electrodes of the same dimensions as the brass electrodes of the ISO/NCB.

A digital megohmmeter, Metronhm model DMH 251A, was used to measure the surface resistance. Its precision is 0.1 Mohm below 100 Mohm and 1 Mohm above; its range is 0-2000 Mohm, and it applies 250, 500 or 1000 V. All the measurements in this report were obtained using 500 V. However, a number of measurements were repeated using 250 and 1000 V. In all cases, the differences were less than 1%.

In general, a steady-state reading was obtained within about 10 s of applying a voltage to a sample. For one product (No. 4), however, the reading did not stabilize for nearly a minute. One minute is the usual time that standards specify for the time of application of the voltage.

RESULTS

REPRODUCIBILITY OF METHODS

The ISO/NCB method often yields results differing by 30%, sometimes more than 100%. For example, Fig. 1 shows the results on two identical samples, carried out simultaneously so as to reduce the possibility of effects due to the surroundings. Although there is a large increase in the difference as the temperature decreases, the percentage difference is roughly constant.

On the same product, five tests carried out simultaneously using the CENELEC method yielded much more reproducible results (Fig. 2). The maximum deviation between the highest and lowest values at any temperature was about 20%, and was not dependent on temperature. Figures 3-5 show that the same magnitude of reproducibility can be obtained with the CENELEC electrodes on products from three other manufacturers.

COMPARISON OF METHODS

The measured surface resistance is shown in Fig. 6-10 using (1) the ISO/NCB method; (2) the ISO/NCB snap of electrodes painted on with silver; and (3) the CENELEC method. [In the legend, "circ.electrodes-liquid" refer to method (1); "circ.electrodes-silver" refer to method (2); and "rect.electrodes-silver" refer to method (3)]. The points on curve 1 of Fig. 6 are the average of the 2 points of Fig. 1; the points on curve 3 of Fig. 7 are the average of the 5 points of Fig. 3.

The ratio of curve 1 to curve 2 ranges from 0.7 to 1.2. If both methods gave perfect contact with the surface of the belting, the ratio would

be 1.0. Since the scatter between tests using the ISO/NCB is of the order of 50%, it is impossible to state that there is a real difference in results between methods 1 and 2.

The ratio of the ISO/NCB method to the CENELEC method ranged from 0.7 to 1.5. The data suggest that there may well be a real difference between the two methods, with the latter yielding higher resistances. However, the difference determined in this work appears to be significantly lower than that found by Sarin (8).

For factoring out the effect of the geometry, methods 2 and 3 should be compared. For samples 1 and 7, the ratios were about 2; for samples 2, 5 and 6, the ratios were about 1. It should be noted that samples 1 and 7 were from one manufacturer and samples 2, 5 and 6 from another manufacturer. Hence, it would appear that the effect of the geometry is a function of the formulation; that is, no general rule can be formulated for estimating the resistance value of one method from the data of another.

RELATIONSHIP BETWEEN RESISTANCE AND TEMPERATURE

All the curves in Fig. 1-10 show a very marked increase of resistance with decreasing temperature. It has been suggested that resistance of insulators should follow the Arrhenius Law (4):

$$k = A e^{-E/RT} \quad (1)$$

where: k is a rate constant

E is an activation energy

T is the absolute temperature

R is the gas constant

A is a constant.

If so, then a plot of $\ln$ Resistance vs $1/T$ would be a straight line, with slope of $-E/R$ and intercept $\ln k$. However, such a plot does not yield a straight line. The data appear to follow a hyperbolic curve with a cut-off at some temperature, below which the resistance is essentially infinite. Therefore, each set of data was fitted to an equation of the form:

$$R = c(T - T_0)^{-b} \quad (2)$$

where: R is the surface resistance

T_0 is the temperature at which the resistance becomes infinite

c and b are positive constants.

Equation 2 was converted to the alternative form:

$$\ln R = \ln c - b(T - T_0) \quad (3)$$

to allow analysis by linear least squares. Equation 3 has 3 parameters; the way of fitting the data was to vary the value to T_0 , until the coefficient of correlation of the least squares fit was maximized. The parameters of such a fit to each of the curves shown in Fig. 1-10 are shown in Table 2.

Graphs 11-19 show how well the data fits Eq [2]. In most cases, the coefficient of correlation exceeds 0.999. Over the range of temperatures used, there are no signs of any non-linearity for any of the data sets.

For some materials, the reproducibility of the empirical parameters (for a given electrode arrangement) was very good (Fig. 11,12), but for others, the reproducibility of the parameters was poor (Fig. 15,16) even though the actual resistance values were quite close.

The data suggests that ISO/NCB method yields a slightly lower T_0 than the CENELEC method. Use of the silver paint rather than the liquid contact agent seems to yield a slightly higher T_0 , though the data are not sufficient to provide a definite conclusion.

Most of the data sets, regardless of manufacturer, yielded values of T_0 around -25°C . These products are all PVC-based; thus there may be an intrinsic characteristic of that material which yields that type of curve. For example, the products become significantly more rigid as the temperature decreases. The ability of the charge to flow freely throughout the material might be correlated with the rigidity.

Figure 20 shows the variation of the surface resistance of a nitrile rubber cover sample with temperature for the three different electrode arrangements. The data is more scattered, probably due to the small values involved. Although the resistance decreases with increasing temperature, the

reduction is much smaller than for the PVC products. Products 9 and 10 had surface resistance values of less than 1 Monm at 20°C; no significant change in resistance with temperature could be observed in the range of 0 to 40°C.

EFFECT OF HUMIDITY

Figure 21 shows the effect of humidity on the surface resistance at several temperatures for sample #2 using the ISO/NCB electrodes (liquid contact agent). Above about 85% R.H., the readings were not stable; they fluctuated 5-20% during the 1 minute measuring period. The liquid contact agent absorbed water from the atmosphere as evidenced by a decrease in viscosity of the agent and the tendency to spread into the gap between the electrodes.

The data indicate that surface resistance decreases only very slightly with increasing humidity up to about 80%, after which the resistance decreases sharply. The unstable readings at high humidities are probably at least partly due to the normal fluctuations of the environmental chamber combined with the steep slope of the resistance/humidity curve in that region. The cause of the sharp decrease may be due to adsorption of water on the surfaces of the sample. More detailed investigation of this phenomenon is not justified from the safety point of view, since it tends to decrease the surface resistance and thus the possibility of electrical discharge.

In order to verify that the sharp decrease in resistance at high humidity was not due to the use of the liquid contact agent, sample #5 was tested using silver paint electrodes (the CENELEC method). Figure 22 shows clearly that the same phenomenon occurs. Other samples were tested in the same way (Fig. 23-2b). The data are all very similar indicating that this is a general phenomenon for PVC belting. The graphs indicate that the relative humidity at which the resistance starts to decrease rapidly is a function of temperature; the lower the temperature, the lower this critical humidity.

DISCUSSION

With respect to sample preparation, Fuller's earth can be difficult to remove after applying. Therefore, it is recommended that distilled water, or an organic solvent that does not affect the properties of the test sample, should be used for cleaning.

Silver paint electrodes are preferred to brass electrodes (plus a liquid contact agent) for the following reasons:

- (a) the results are more reproducible;
- (b) it is much easier to keep the silver paint from spreading into the gap between the electrodes than the liquid;
- (c) the silver paint is permanent; samples can be kept and retested for confirmation of results at a later date;
- (d) testing the variation of resistance with humidity and temperature is much easier - the liquid contact agent has to be reapplied before each test;
- (e) the liquid contact agent often makes an imperfect contact with irregular surfaces; there is no such problem with the silver paint;
- (f) all products, including rigid tubes, can be tested with silver electrodes; thus the same criterion can be applied universally.
- (g) at high humidities, the liquid contact agent absorbs water from the atmosphere, thus changing the conditions of the test.

The advantages of the CENELEC (rectangular) electrodes over the circular electrodes are: economy of labour, less silver paint used and smaller sample size required.

The appropriate value of the maximum allowed resistance to use for the CENELEC method so that it will correspond to the 300 Mohm used for the ISO/NCB method cannot be determined precisely from the results in this report. It is possible that the ratio may be material dependent. The ASTM Standard (4) has an electrode arrangement similar to the ISO/NCB, but with a much smaller gap. In fact, it is specified that the gap must be less than twice the thickness of the material in order for a surface resistivity, which is characteristic of the material and independent of the electrode arrangement, to be determined. The author suggests that 200 Mohm be adopted as the upper limit for the CENELEC method, as an improved estimate over the 120 Mohm used to date.

Relative humidity has a much smaller effect on the surface resistance than expected, except at very high humidities. Hence, precise control of the humidity during testing, although desirable, is not essential. (Normally, the

humidity is kept below 70%). It should be noted that, just because the surface resistance does not change significantly over a wider range of humidity does not mean that the possibility of an electrical discharge is independent of humidity. From common experience, it is known that the probability of electrical discharge increases substantially as the humidity decreases. Hence, measurement of surface resistance by itself cannot be used as a predictor of static electrical hazard. It is useful as a means of eliminating products which may pose such a hazard.

CONCLUSIONS

The very large temperature dependence of the surface resistance of PVC conveyor belting has been identified herein for the first time. This discovery has raised some questions about the limitations of the existing surface resistance tests as a means of ensuring the safety of conveyor belting (and other equipment) with respect to static discharges in a potentially explosive atmosphere. The surface resistance should be measured at the temperature of proposed use, rather than at standard laboratory conditions. Clearly, in warm locations, the existing test is sufficient; however, in cold countries such as Canada, PVC conveyor beltings may become essentially non-conductive and thereby be susceptible to the build-up of static charges.

Further work on the effect of temperature and humidity on the surface resistance of other types of products and materials would be desirable. The direct measurement of the energy of an electrical discharge from the surfaces of materials with different surface resistances as a function of temperature and humidity would be useful as a means of establishing appropriate maximum values of surface resistance.

REFERENCES

1. Eisfeld, D. Gluckauf-Forschungshefte 45:116; 1984. (Health and Safety Executive (U.K.) Translation No. 10904).
2. Glor, M. J. Electrostatics 10:327; 1981.
3. Kolodziej, J. 17th International Conference of Safety in Mines Research, Bulgaria 177; Oct. 1977. (Health and Safety Executive Translation No. 7295).
4. American Society for Testing and Materials Standard D257-78 "Standard test method for D-C resistance or conductance of insulating materials"; 1978.
5. International Standards Association 284-82, "Conveyor belts-electrical conductivity-specification and method of test".
6. National Coal Board specification No. 158/1980; "Fire-resistant conveyor belting"; 1980.
7. European Committee for Electrotechnical Standardization (CENELEC), European Standard En 50 014, "Electrical apparatus for potentially explosive atmospheres - general requirements"; 1977.
8. Sarin, N.K. "Comparison of test standards used at CEAL for evaluation of antistatic properties in fire-resistant materials"; CANMET Division Report ERP/MRL 83-b9(TR).

Table 1 - Conveyor belting samples tested

Sample No.	Manufacturer	Type of cover
1	A	Polyvinylchloride
2	B	Polyvinylchloride
3	C	Polyvinylchloride
4	D	Polyvinylchloride
5	B	Polyvinylchloride-thick coating
6	B	Polyvinylchloride
7	a	Polyvinylchloride-thick coating
8	A	Nitrile rubber
9	B	Nitrile rubber
10	E	Rubber/steel cord

Table 2 - Best-fit parameters of surface resistance data to Eq 2

Sample No.	Data from:			-b	In c	Plotted in:	
	Fig. #	Curve #	T (°C)			Fig. #	Curve #
1	1	1	-36	7.20 ± .04	33.4 ± .1	11	1
1	1	2	-36	7.33 ± .06	34.2 ± .2	11	2
1	2	1	-23	5.44 ± .03	24.4 ± .1	12	1
1	2	2	-24	5.61 ± .03	25.2 ± .1	12	2
1	2	3	-23	5.47 ± .02	24.6 ± .1	12	3
1	2	4	-21	5.20 ± .03	23.3 ± .1	12	4
1	2	5	-22	5.34 ± .02	24.1 ± .1	12	5
1	6	2	-30	6.37 ± .03	29.7 ± .1	13	1
1	6	3	-30	6.37 ± .03	29.1 ± .1	13	2
2	3	1	-24	4.72 ± .03	21.8 ± .1	14	3
2	3	2	-25	4.83 ± .03	22.4 ± .1		
2	3	3	-25	4.80 ± .04	22.3 ± .1		
2	3	4	-22	4.40 ± .03	20.7 ± .1		
2	3	5	-24	4.75 ± .03	22.0 ± .1		
2	7	1	-36	5.90 ± .04	28.0 ± .2	14	1
2	7	2	-36	5.80 ± .05	27.4 ± .2	14	2
3	4	1	-9	4.21 ± .10	21.6 ± .4	15	1
3	4	2	-12	4.57 ± .13	23.3 ± .5	15	2
3	4	3	-27	6.20 ± .13	31.2 ± .5	15	3
4	5	1	-32	6.39 ± .04	30.0 ± .1	16	1
4	5	2	-26	5.57 ± .04	26.2 ± .1	16	2
4	5	3	-35	6.81 ± .05	32.2 ± .2	16	3
4	5	4	-24	5.53 ± .05	25.8 ± .2	16	4
4	5	5	-39	7.61 ± .07	36.1 ± .3	16	5
5	8	1	-38	6.92 ± .03	32.9 ± .1	17	1
5	8	2	-35	6.36 ± .06	30.1 ± .2	17	2
5	8	3	-24	5.44 ± .04	25.1 ± .1	17	3
6	9	1	-28	5.19 ± .04	24.0 ± .2	18	1
6	9	2	-20	4.32 ± .05	20.3 ± .2	18	2
6	9	3	-21	4.83 ± .04	22.1 ± .2	18	3
7	10	1	-27	5.70 ± .05	25.8 ± .2	19	1
7	10	2	-26	5.52 ± .03	25.2 ± .1	19	2
7	10	3	-26	5.58 ± .02	24.9 ± .1	19	3

Fig. 1. Surface Resistance: Sample #1

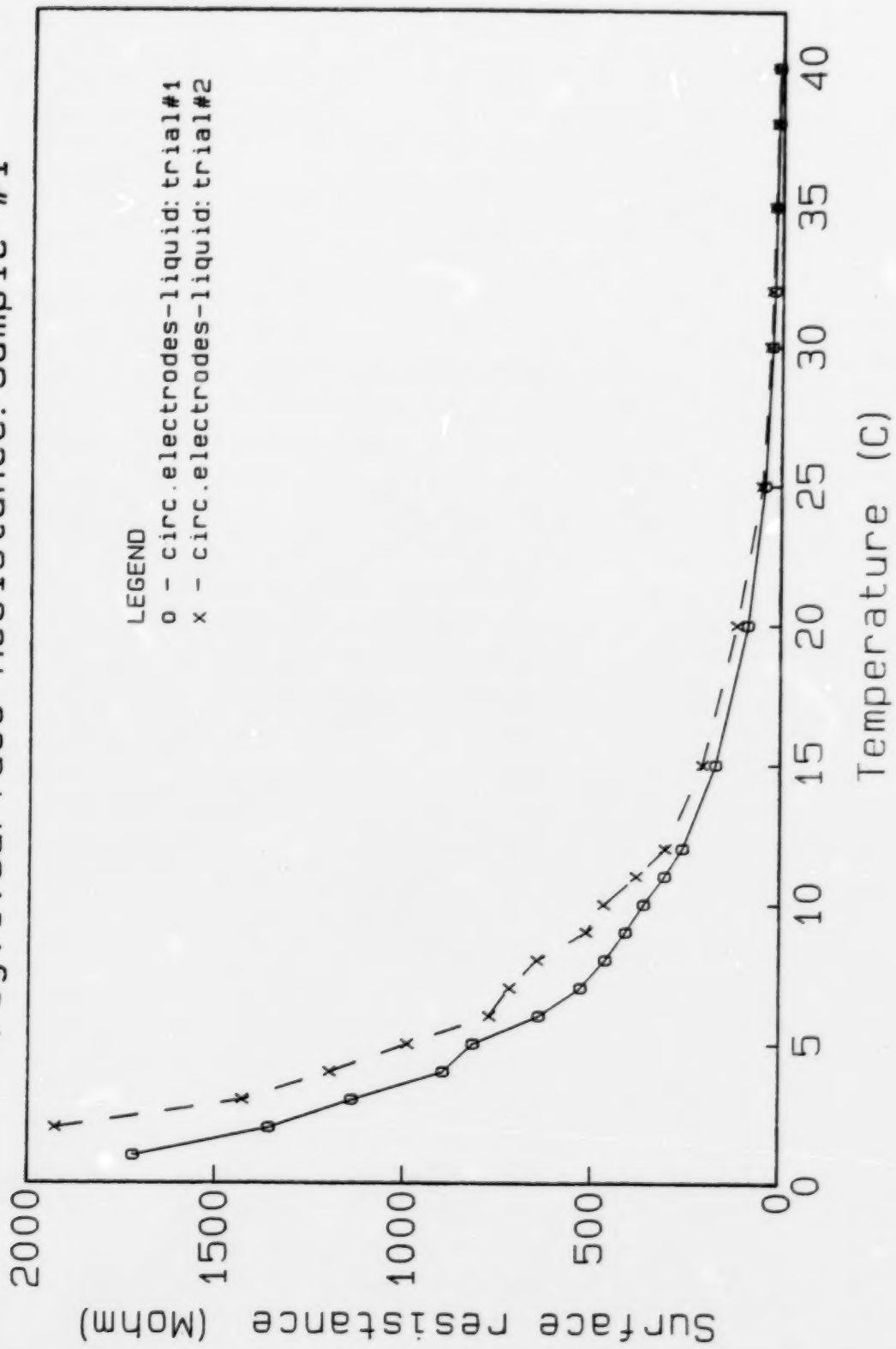


Fig. 2. Surface Resistance: Sample #1

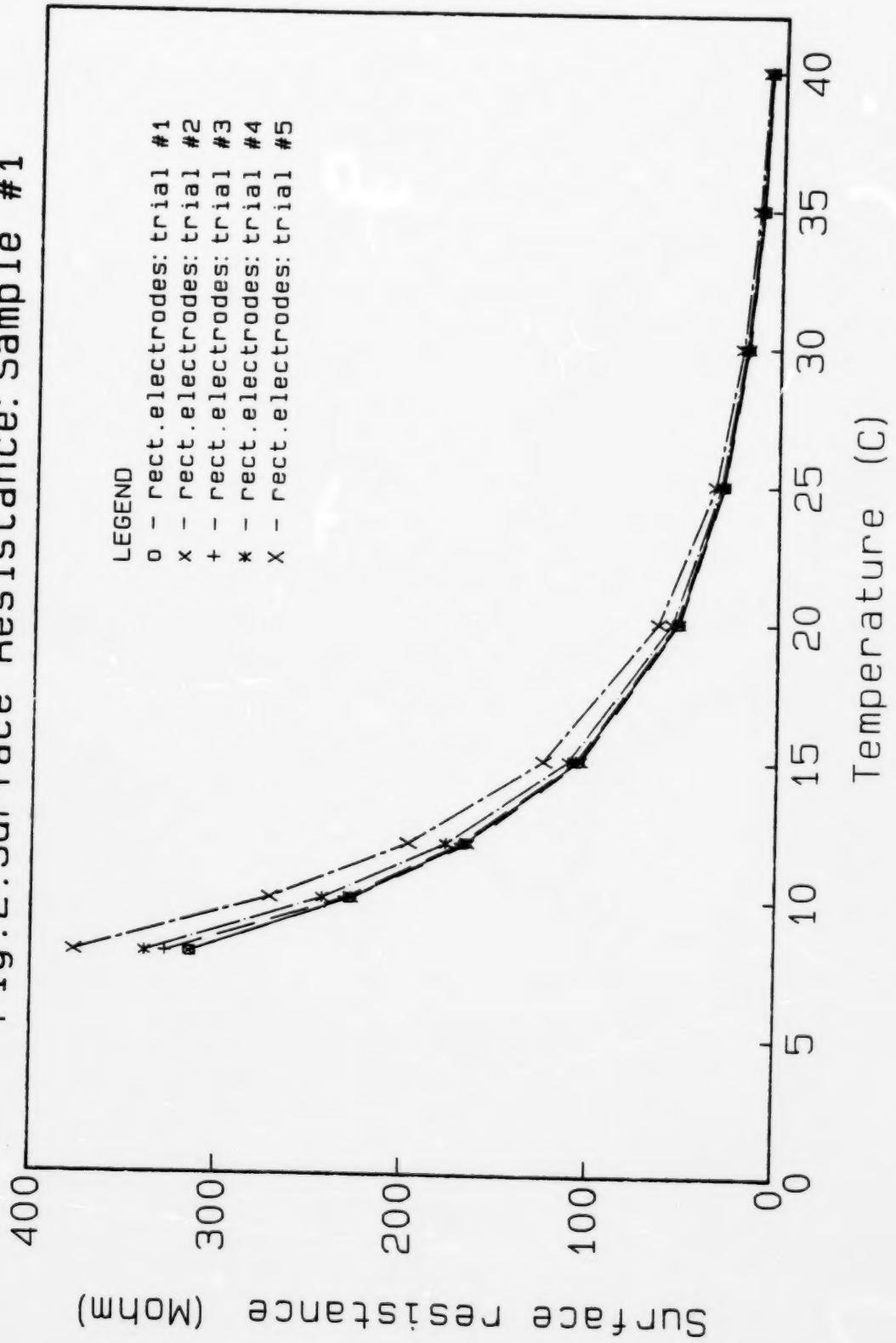


Fig.3.Surface Resistance: Sample #2

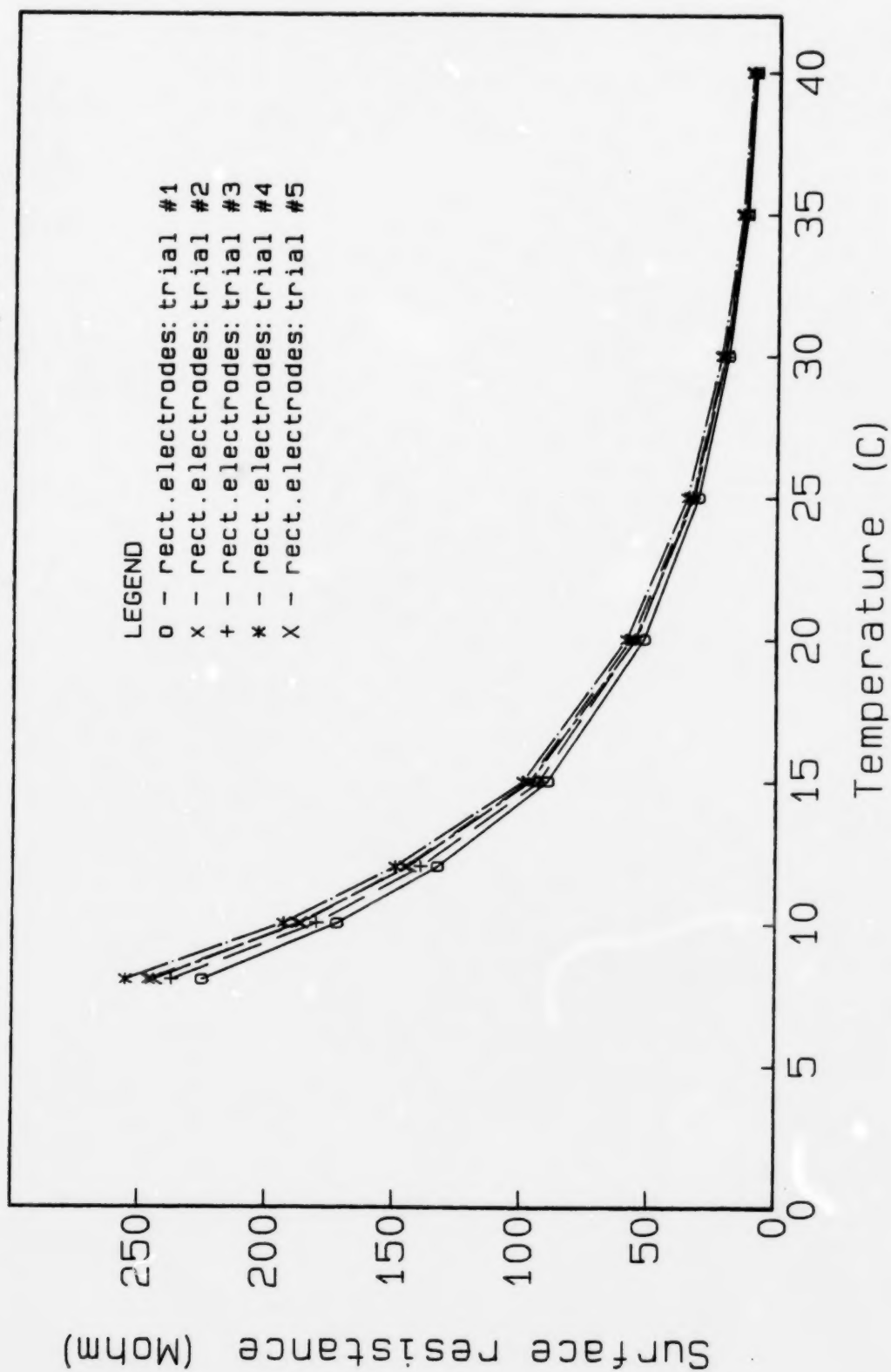


Fig. 4. Surface Resistance: Sample #3

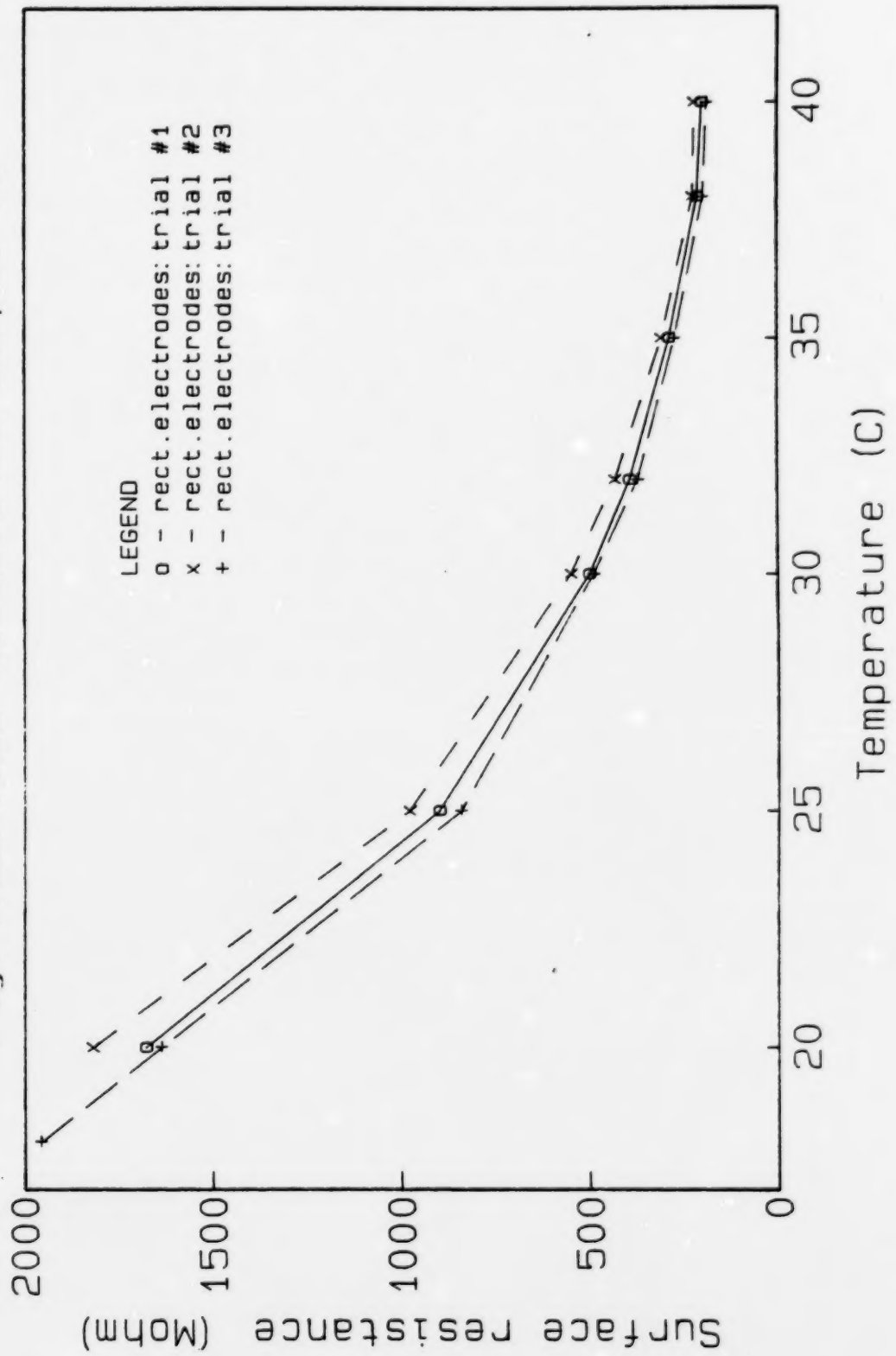


Fig. 5. Surface Resistance: Sample #4

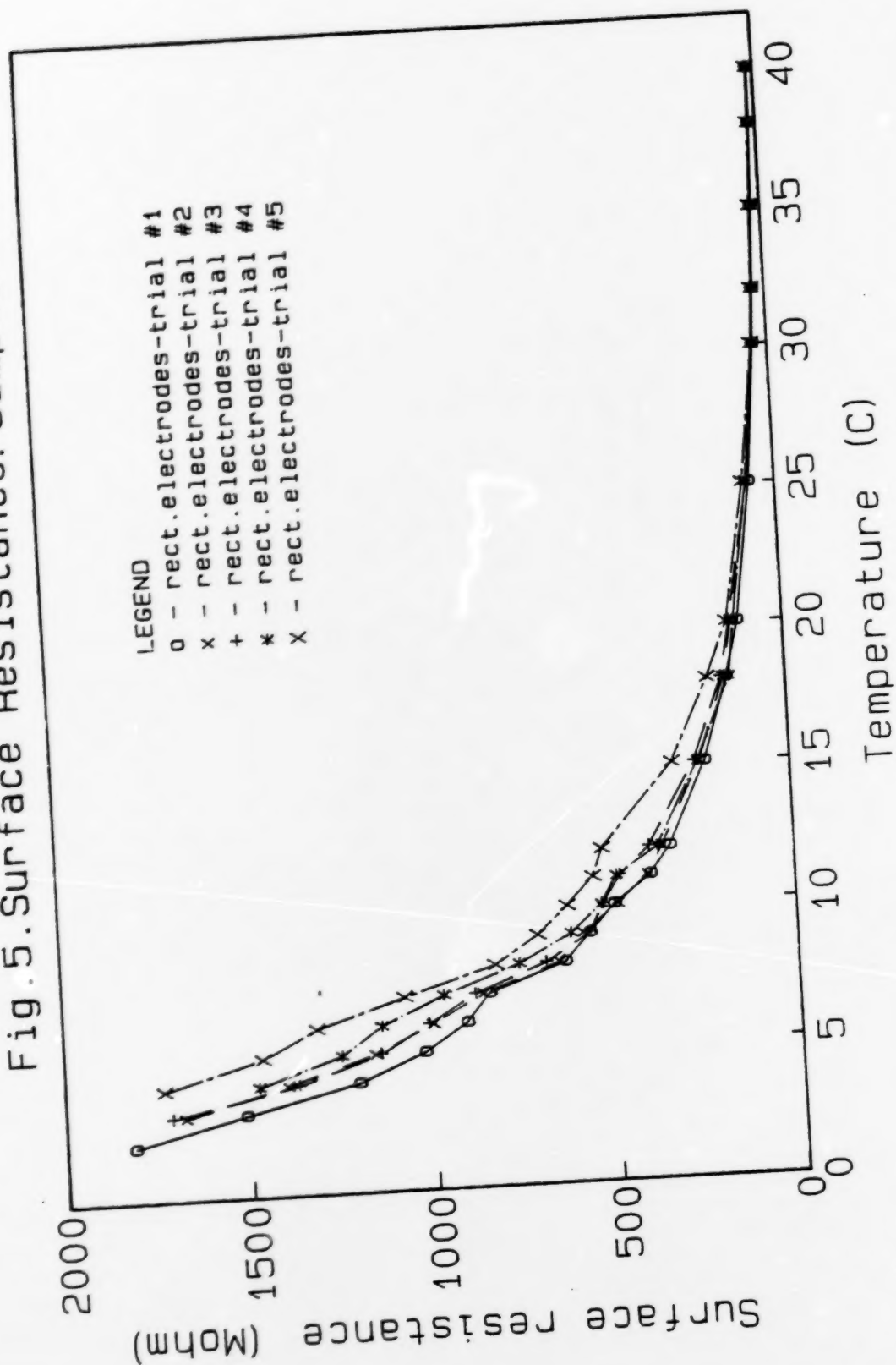


Fig. 6. Surface Resistance: Sample #1

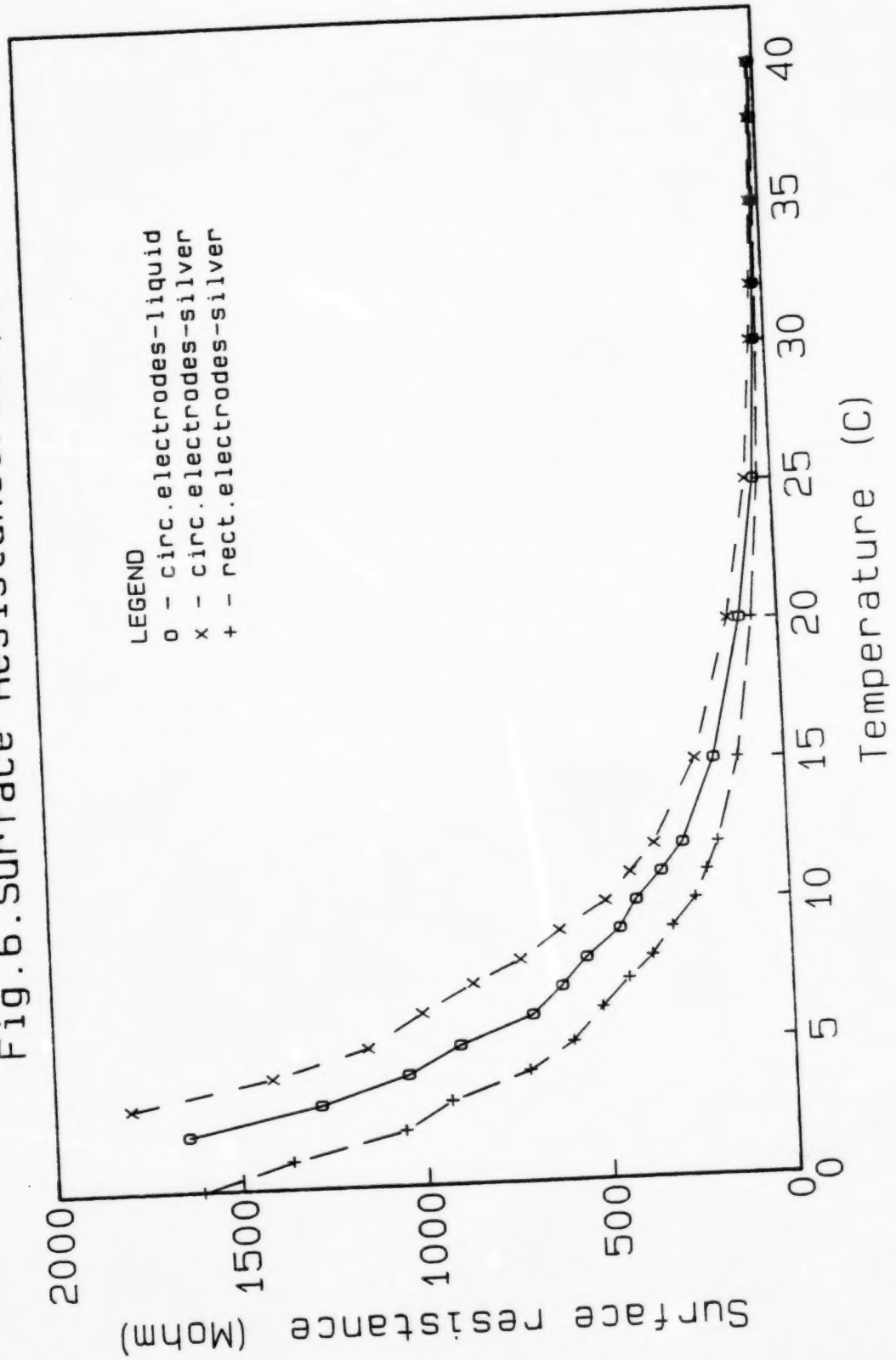


Fig. 7. Surface Resistance: Sample #2

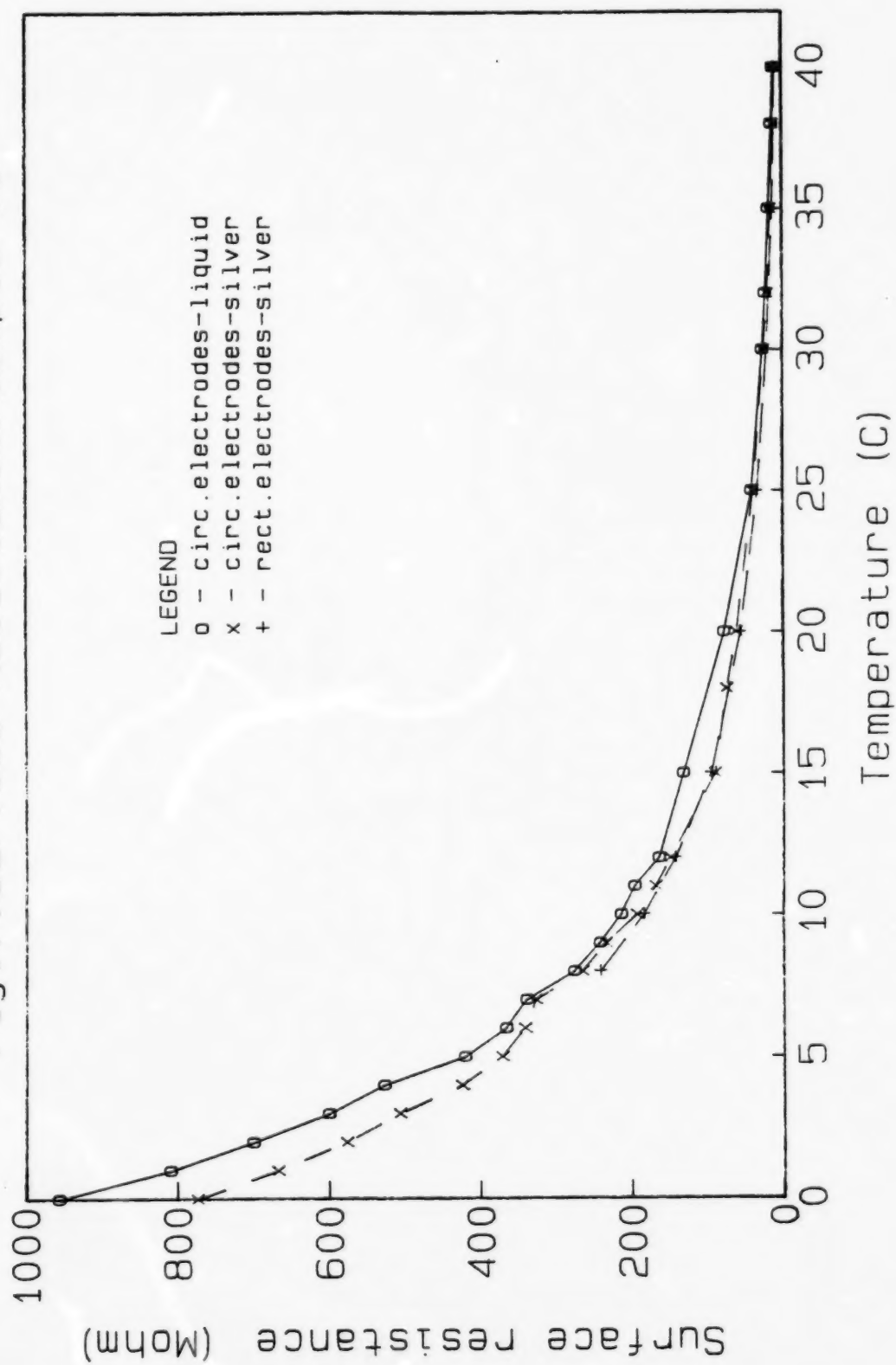


Fig. 8. Surface Resistance: Sample #5

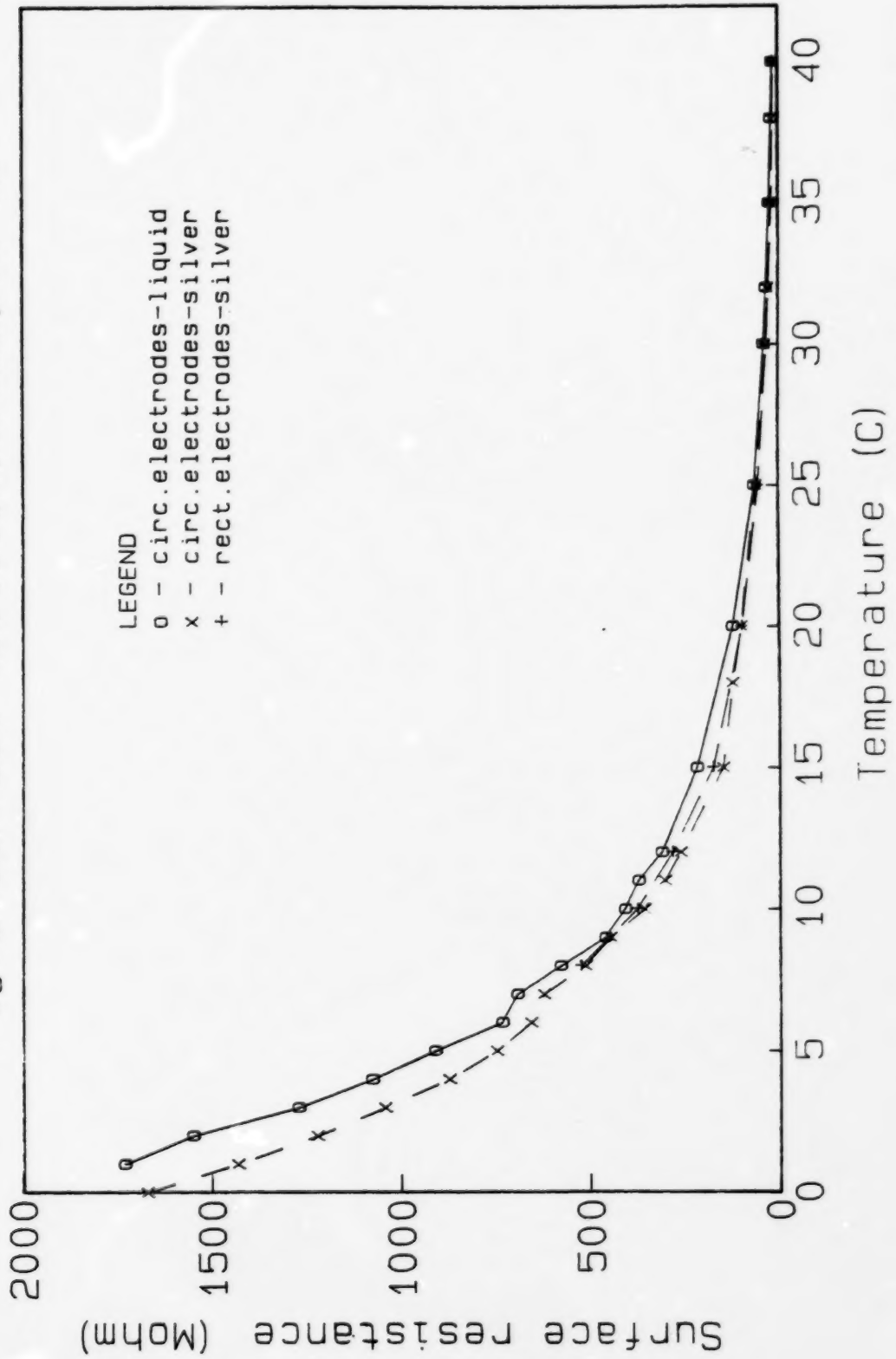


Fig. 9. Surface Resistance: Sample #6

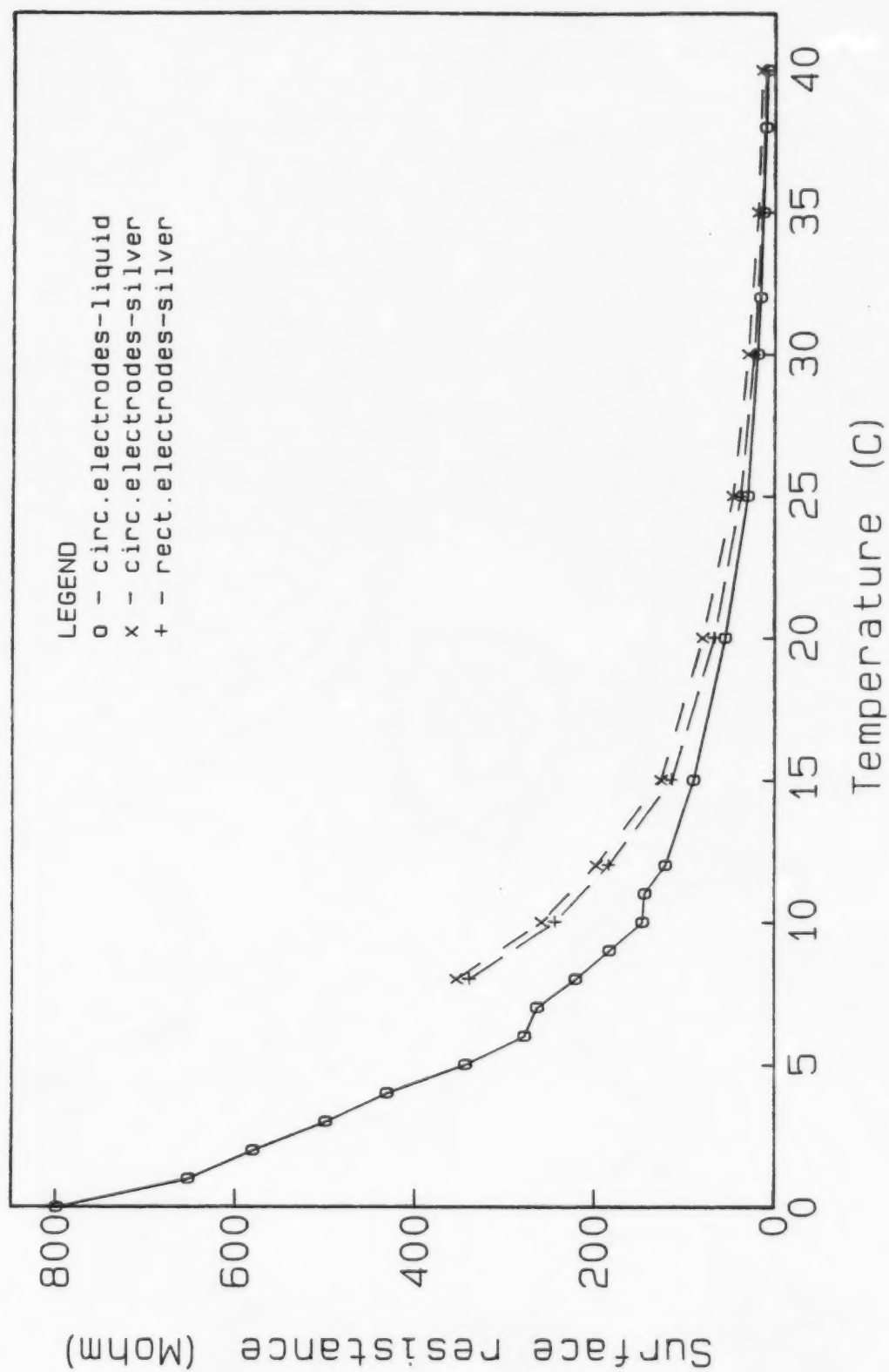


Fig.10. Surface Resistance: Sample #7

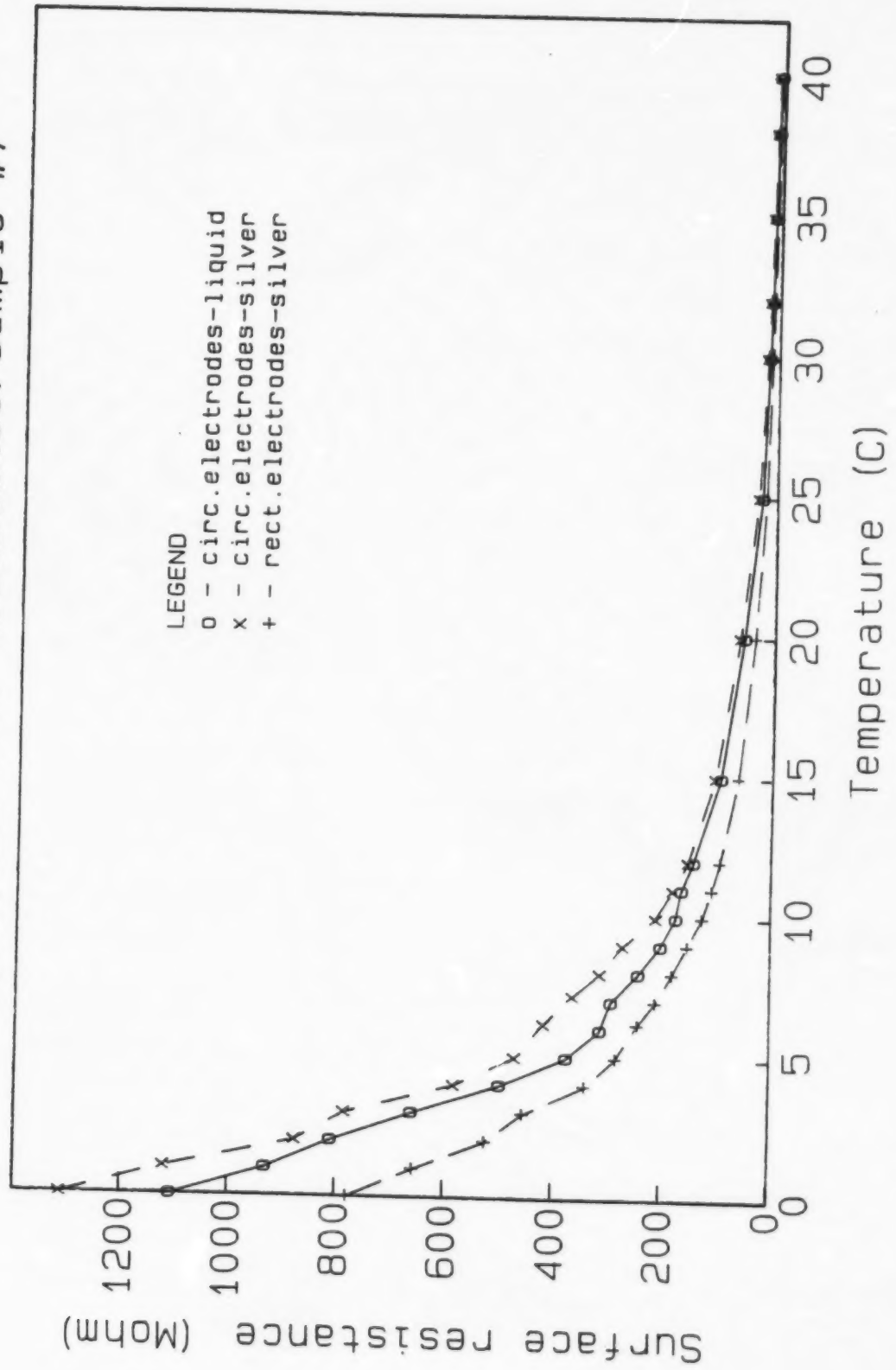
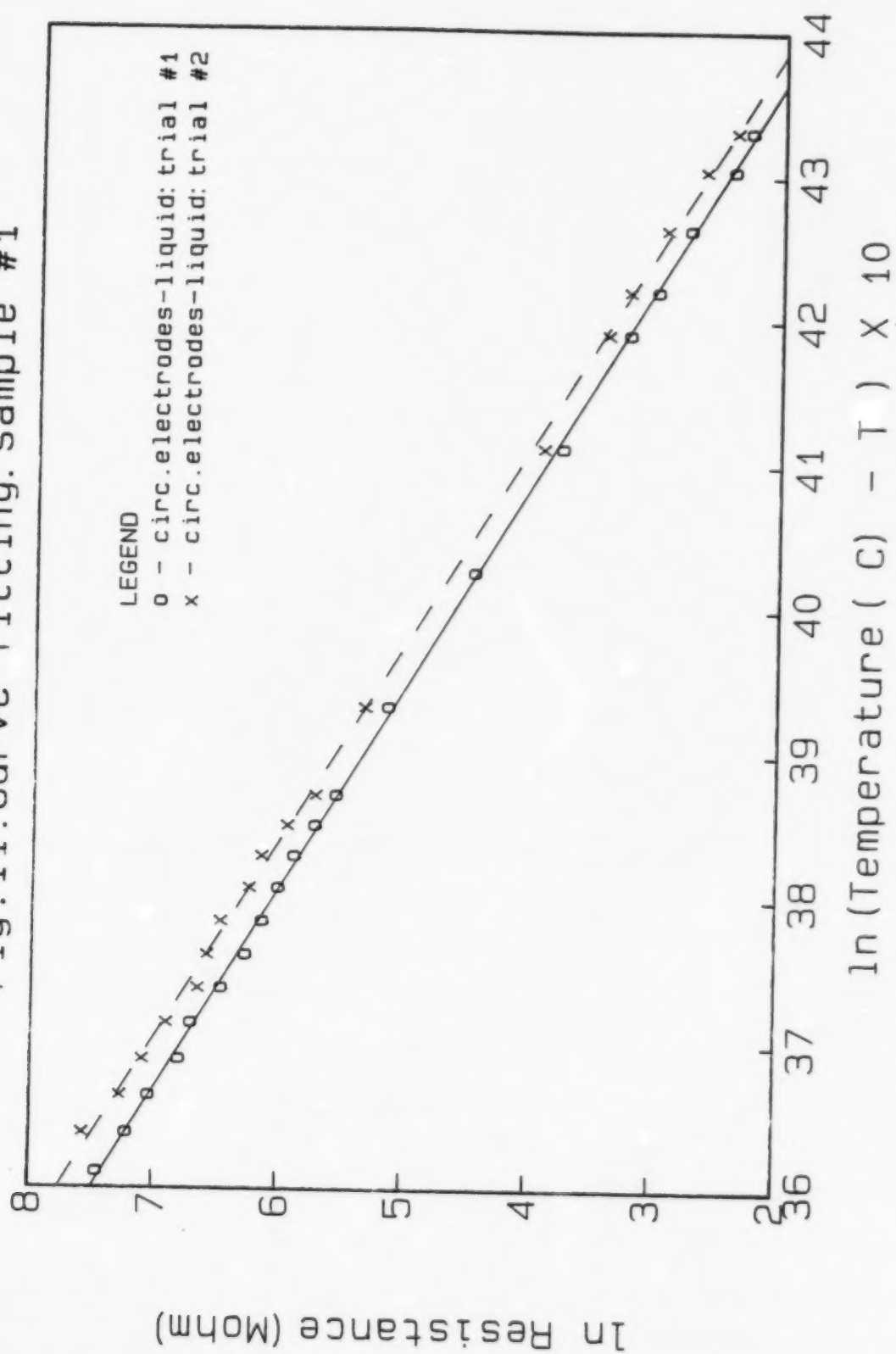


Fig.11. Curve fitting: sample #1



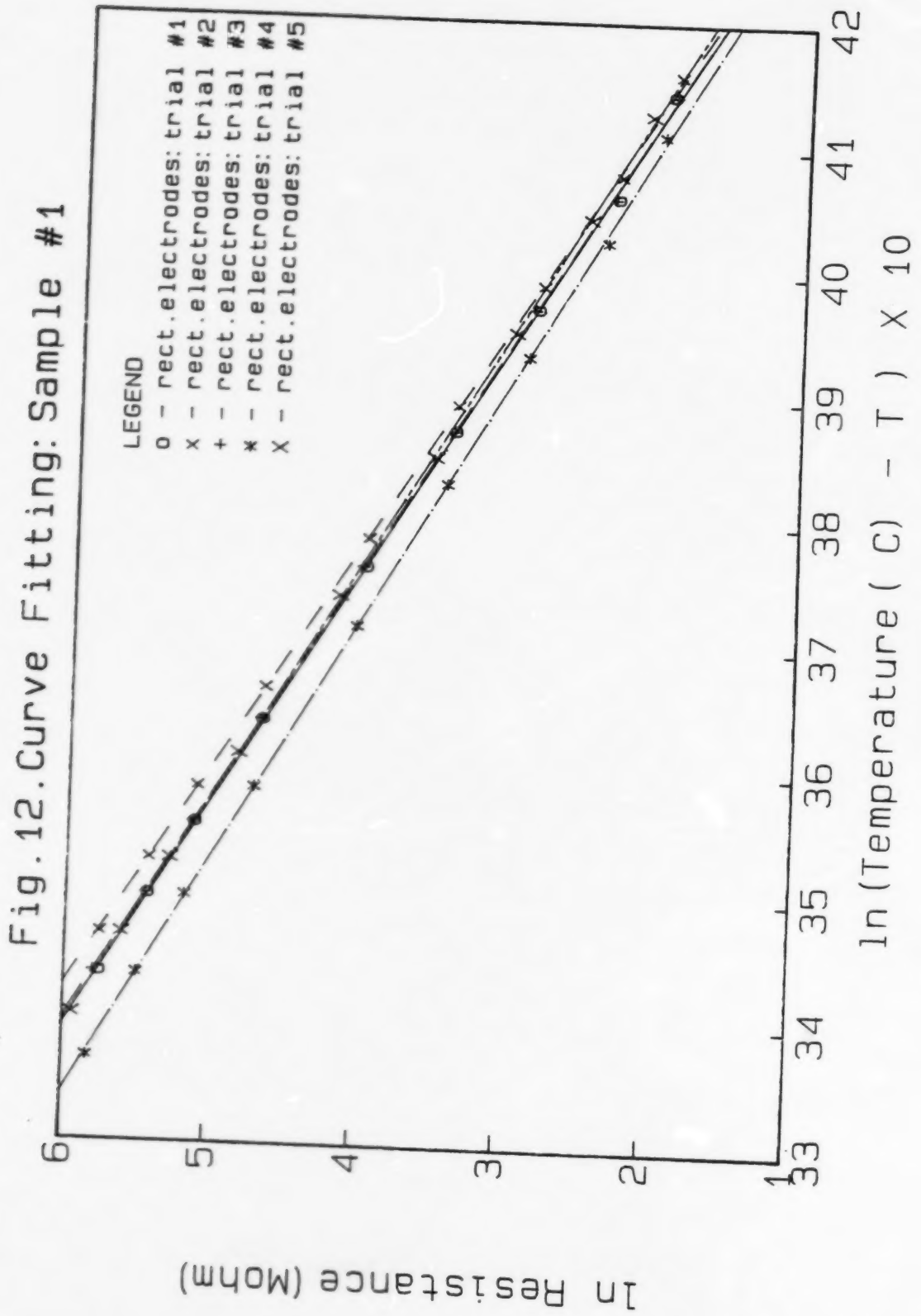


Fig.13. Curve Fitting: Sample #1

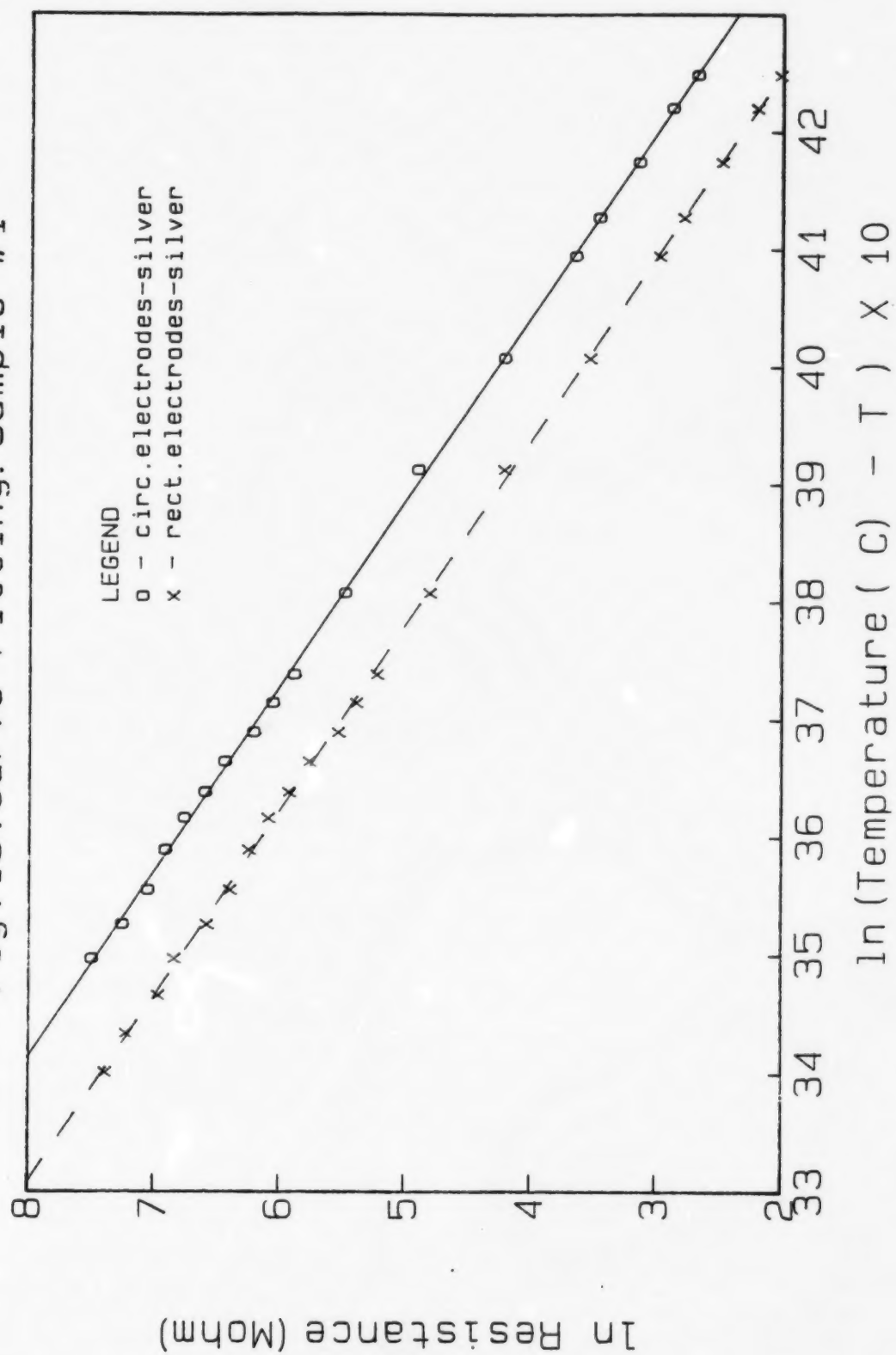


Fig. 14. Curve Fitting: Sample #2

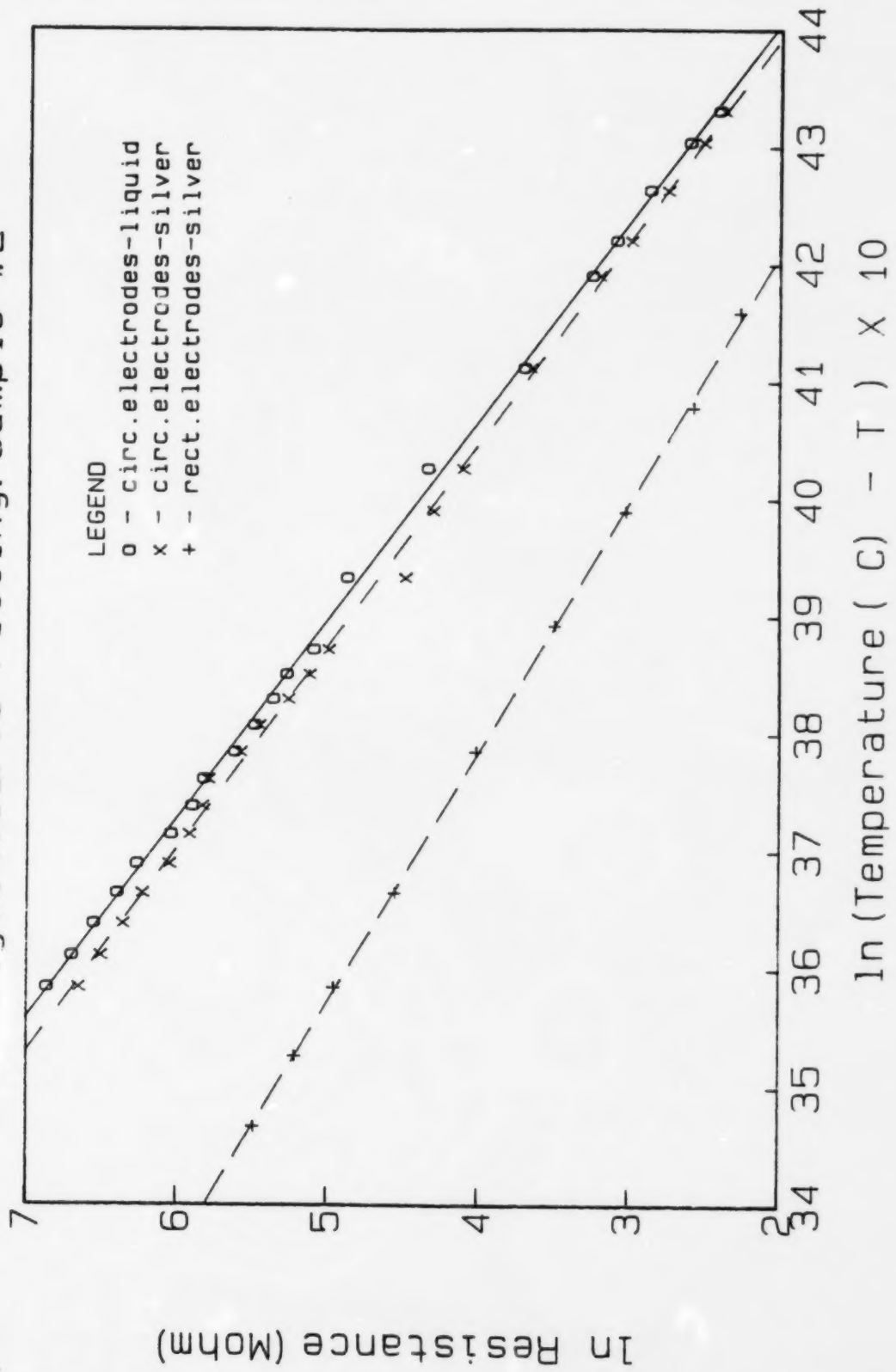


Fig. 15. Curve Fitting: Sample #3

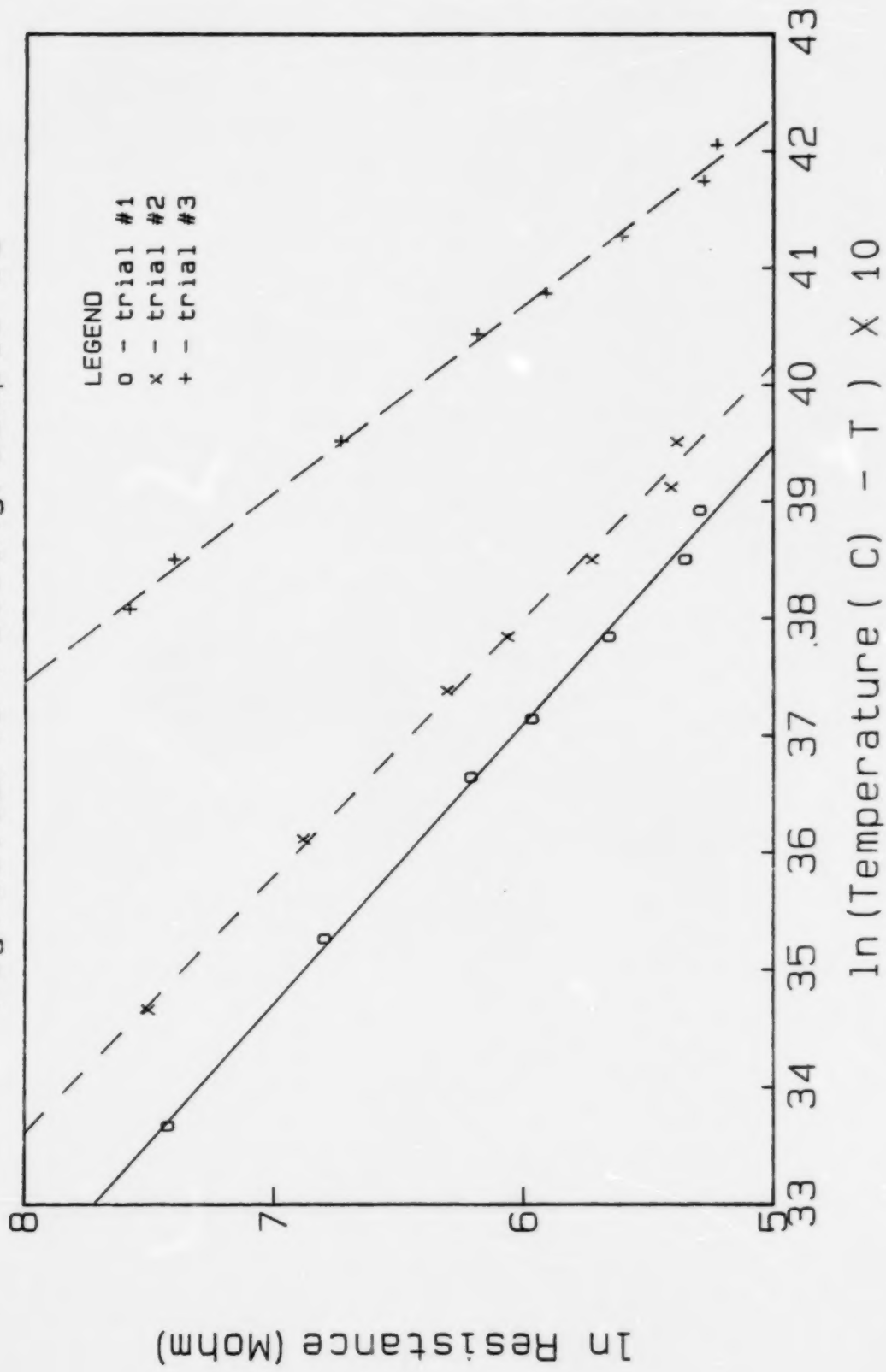


Fig. 16. Curve Fitting: Sample #4

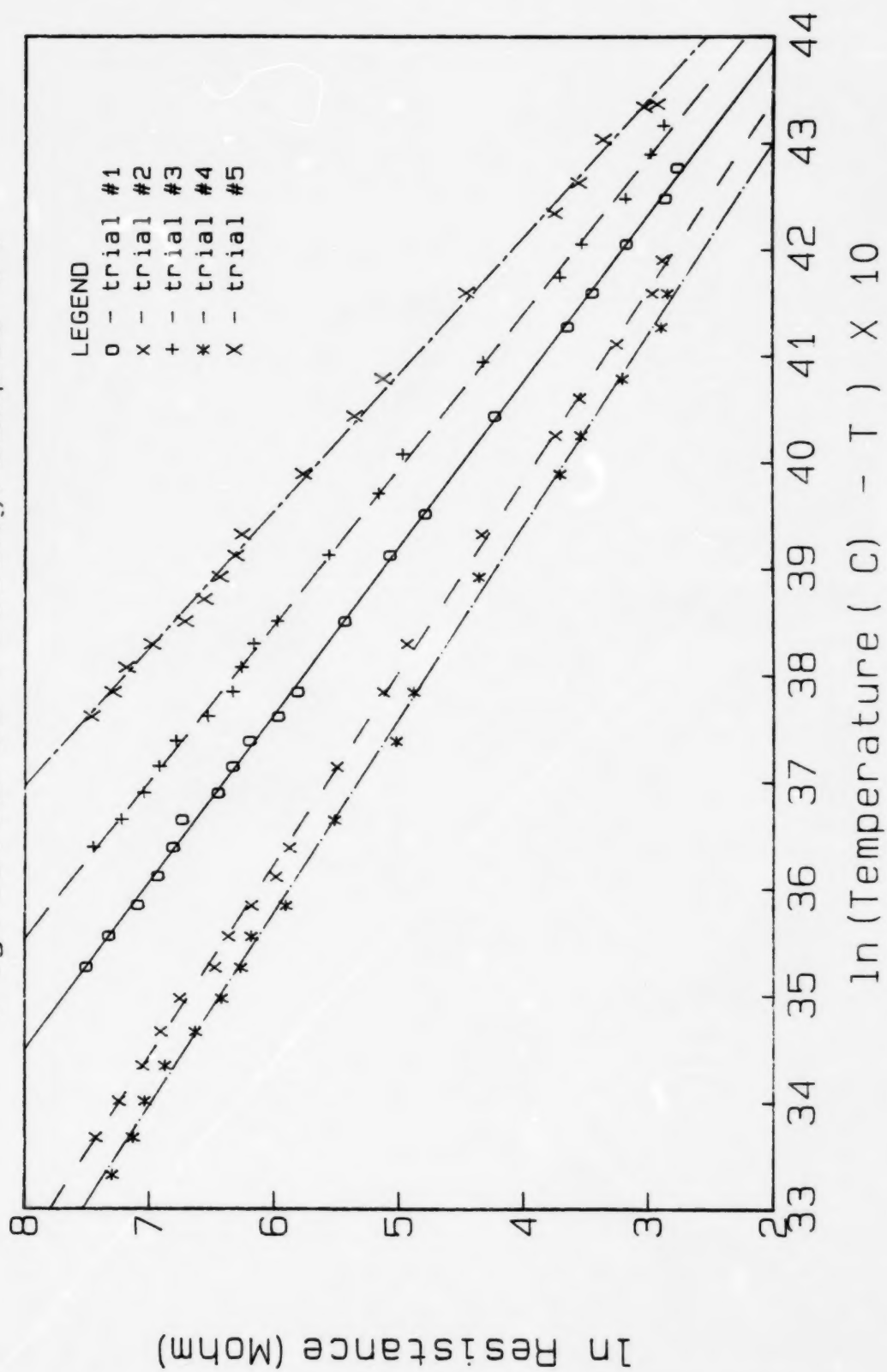


Fig. 17. Curve Fitting: Sample #5

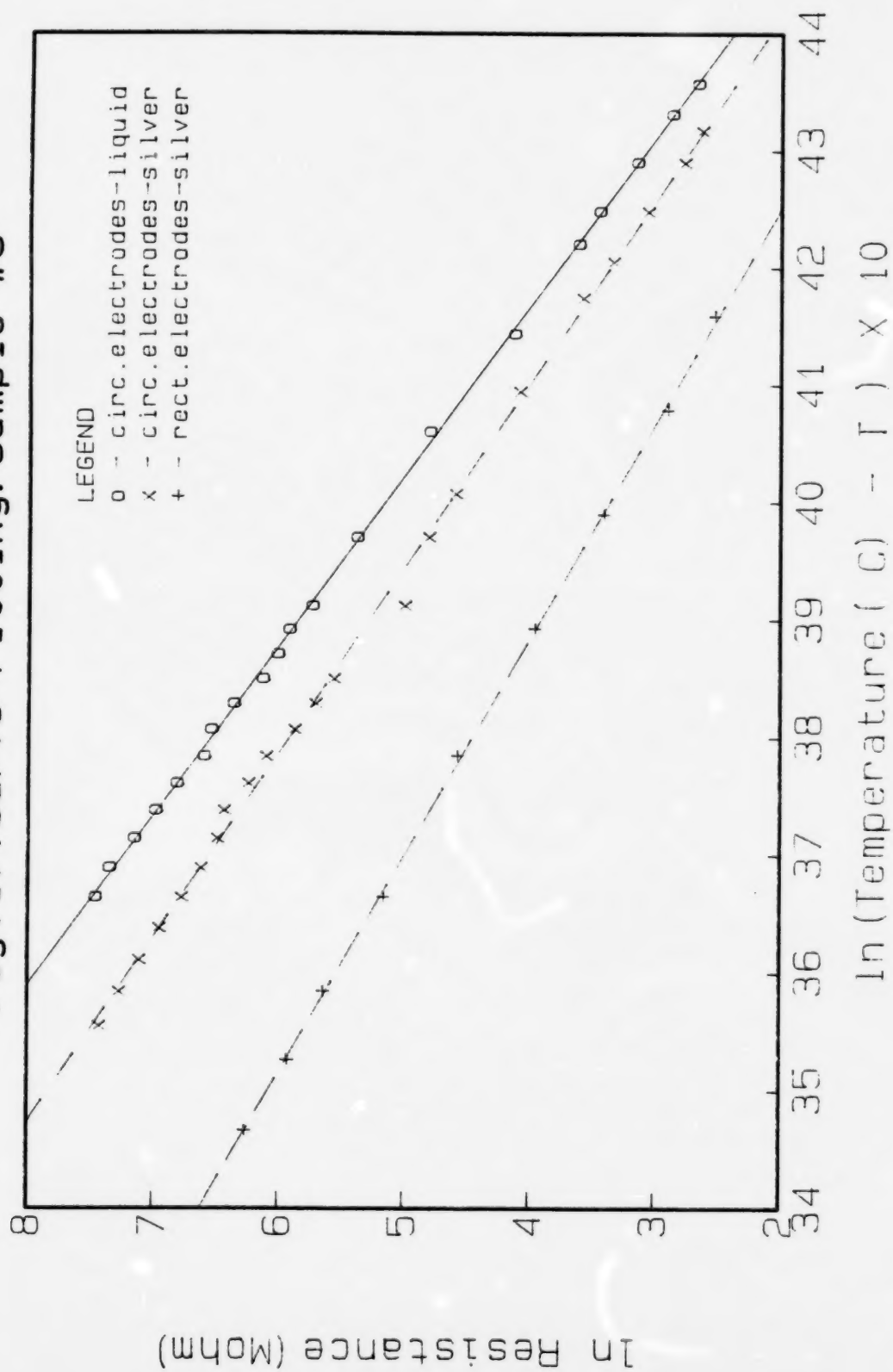


Fig. 18. Curve Fitting: Sample #6

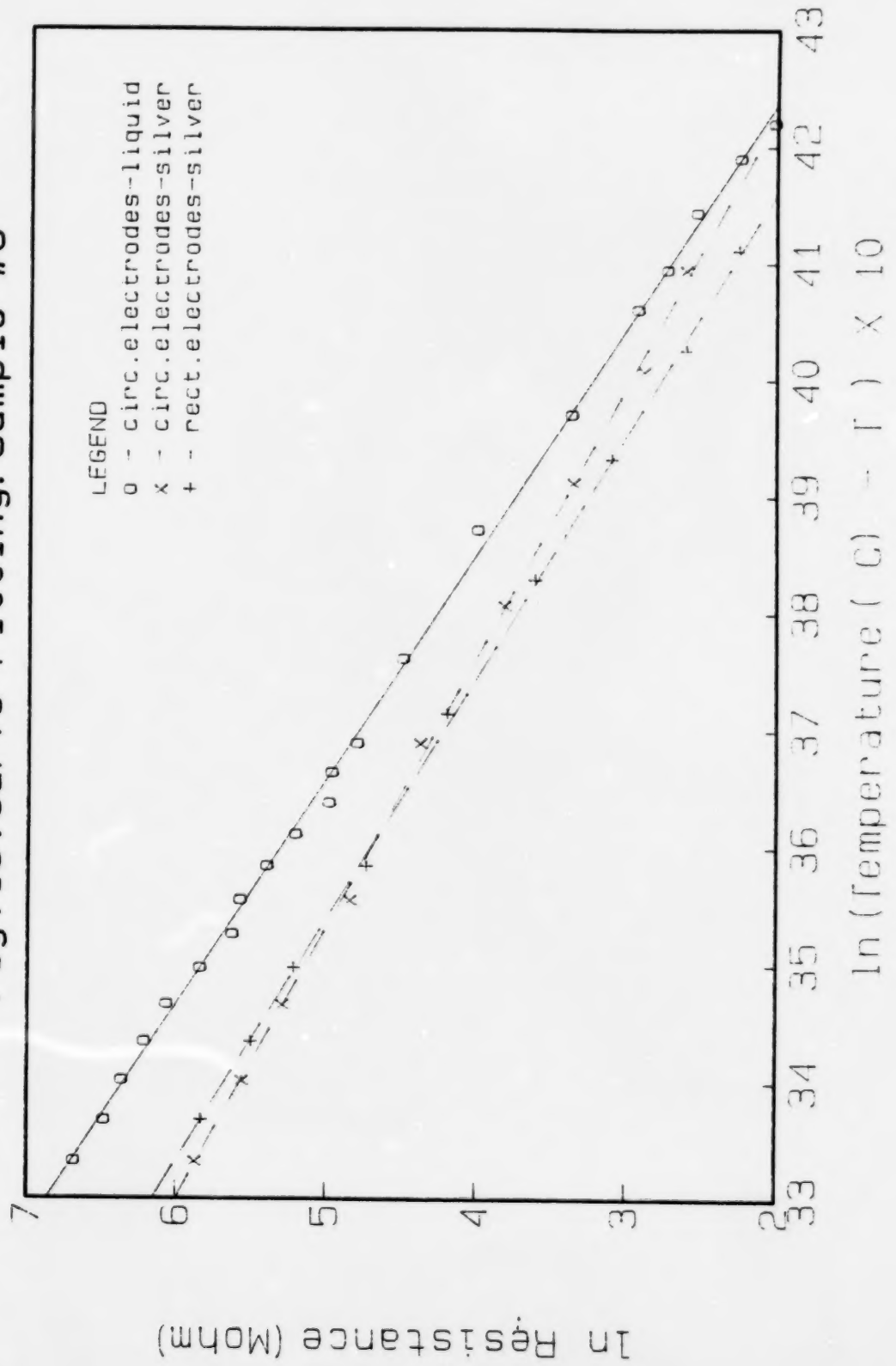


Fig. 19. Curve Fitting: Sample #7

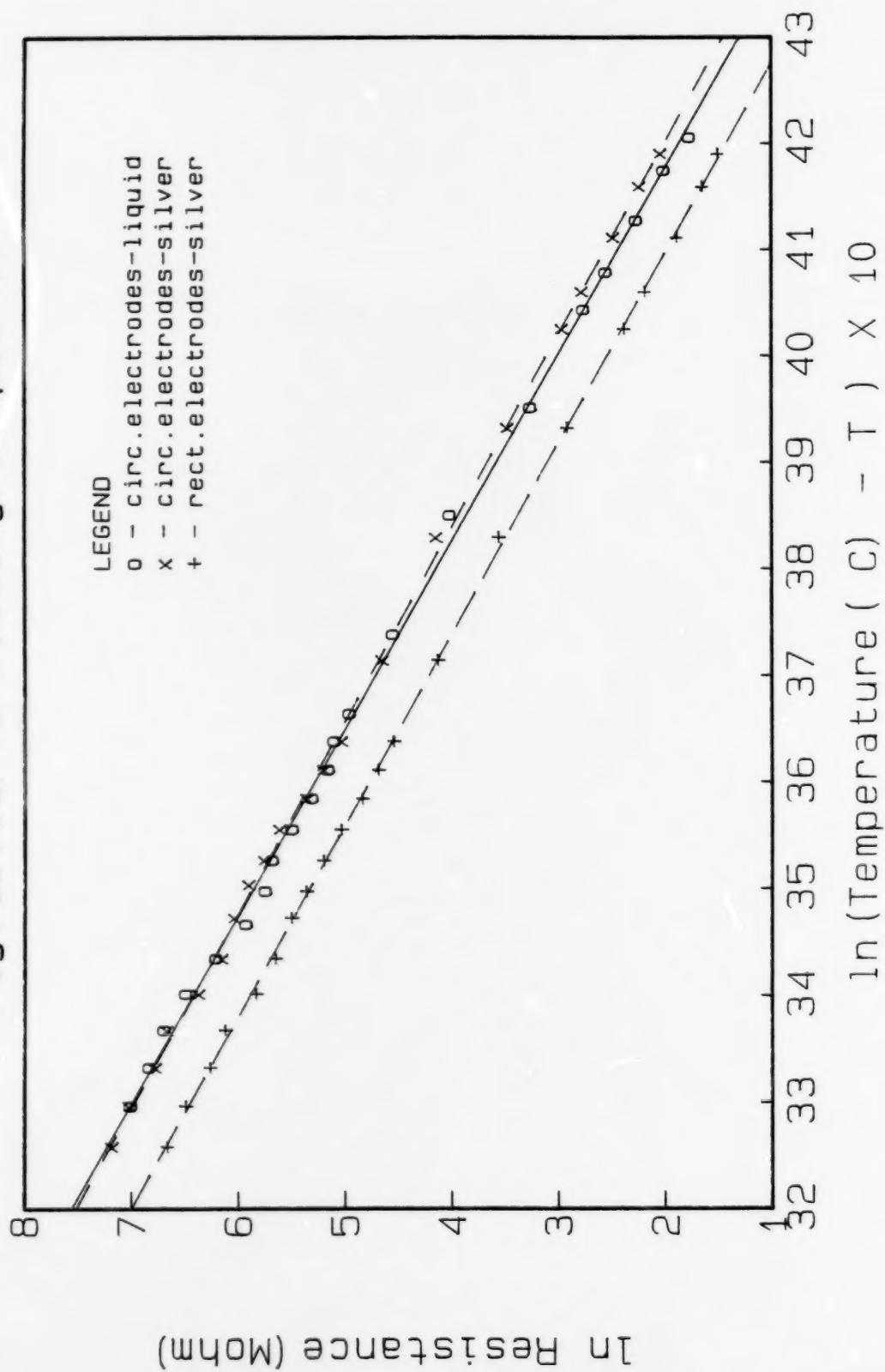


Fig. 20. Surface Resistance: Sample #8

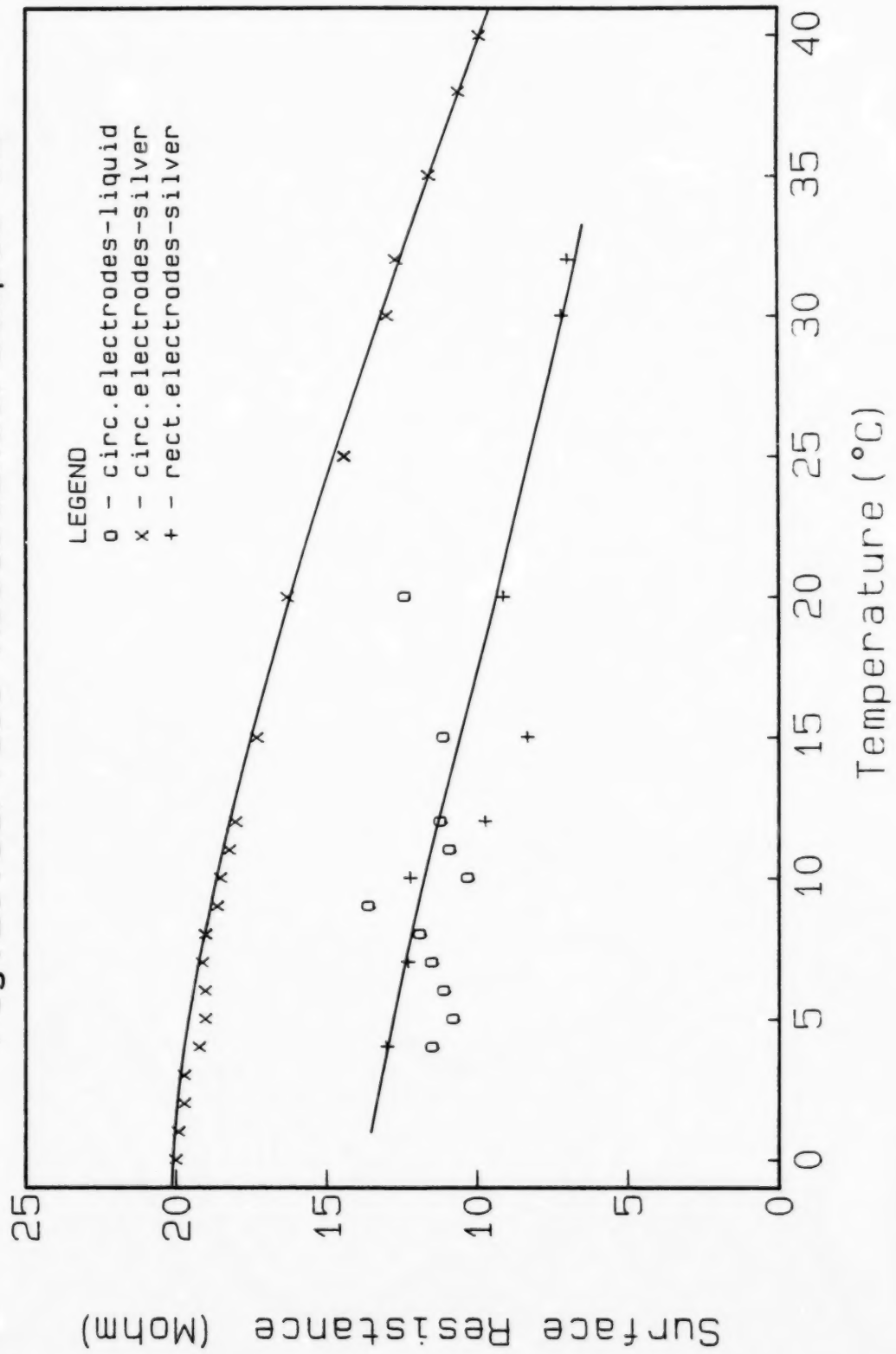


Fig.21.Surface Resistance: Sample #2

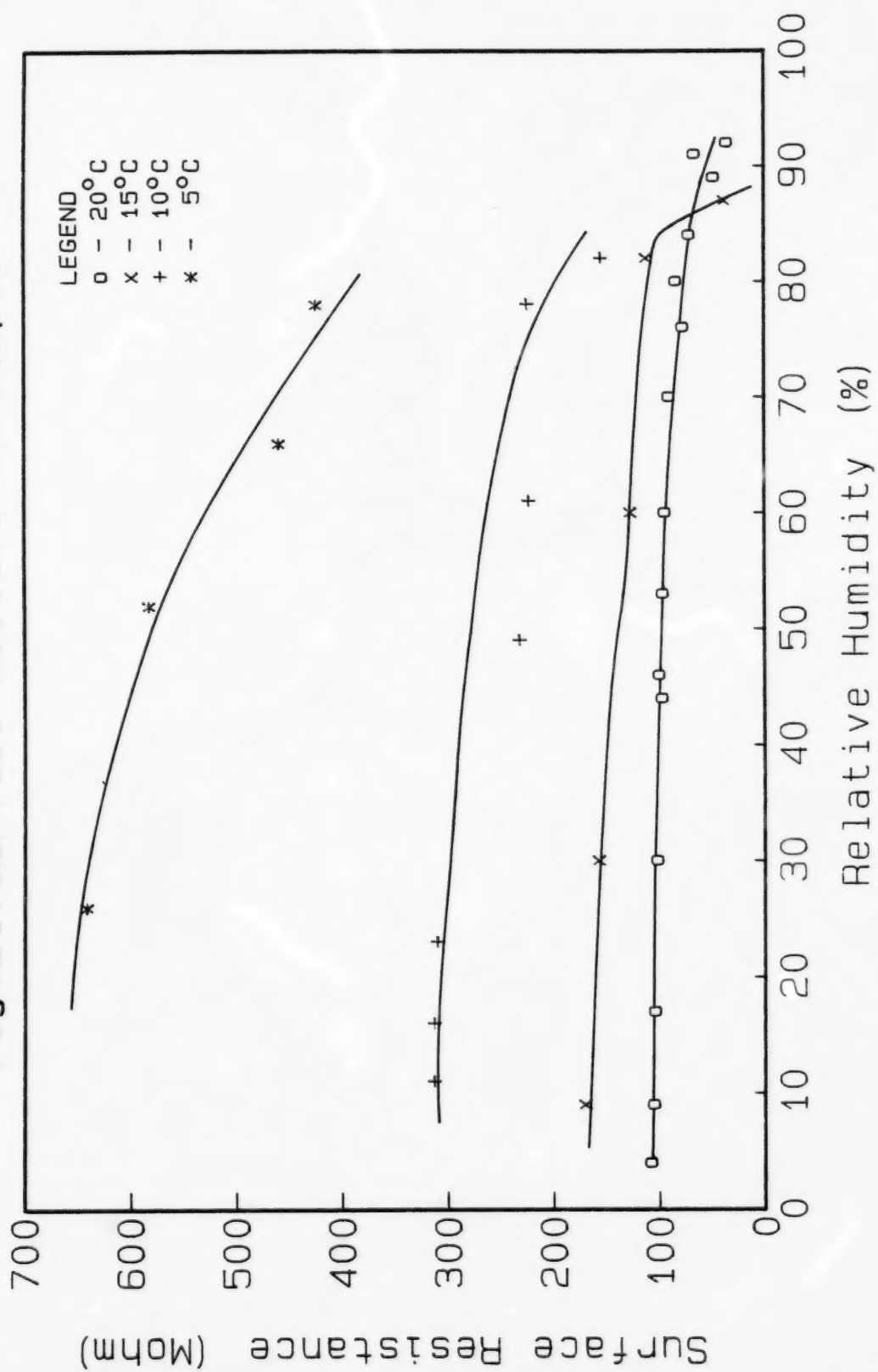


Fig.22.Surface Resistance (CENELEC): Sample #5

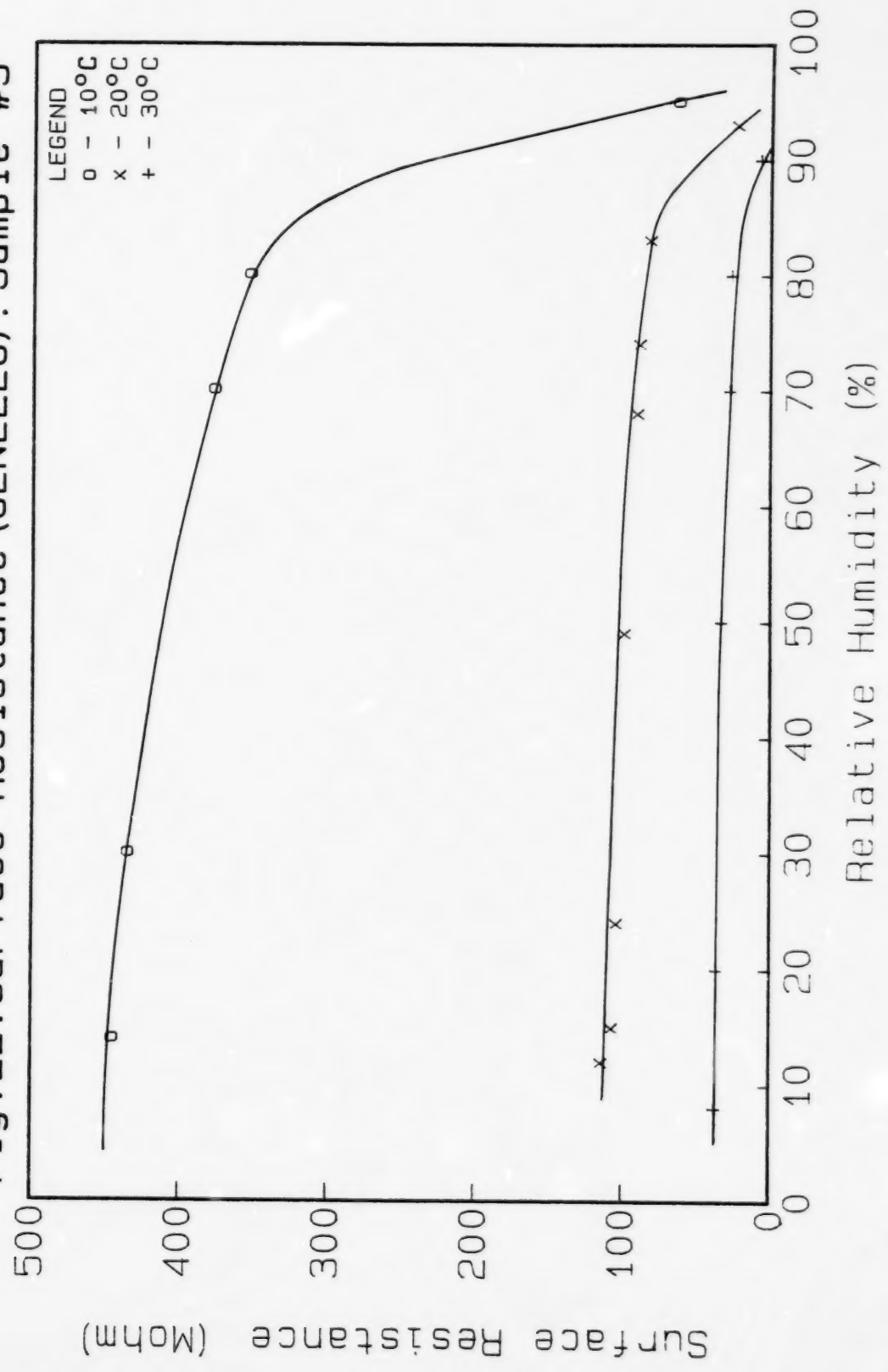


Fig. 23. Surface Resistance (ISO-silver): Sample #6

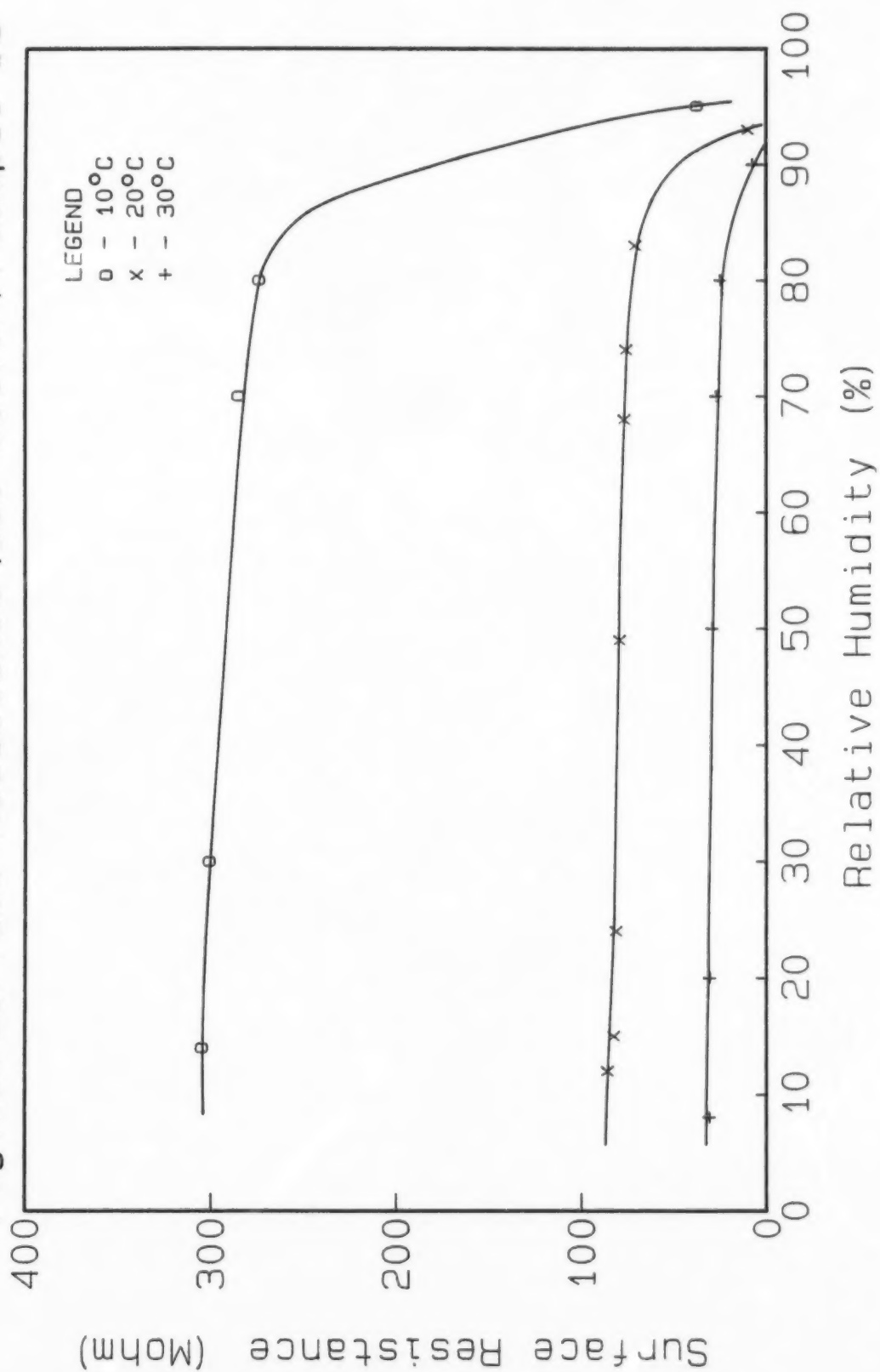


Fig. 24. Surface Resistance (CENELEC): Sample #6

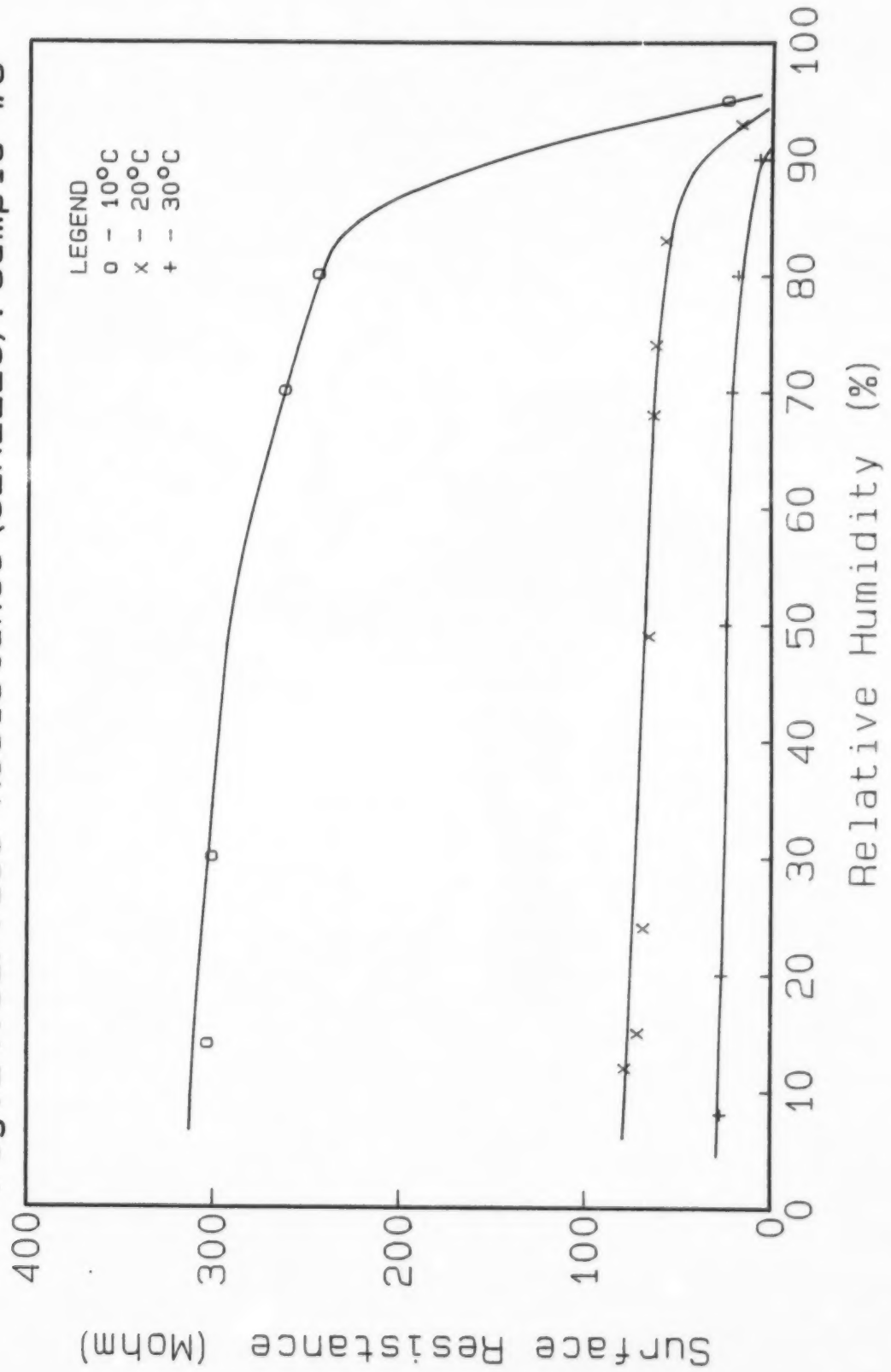


Fig. 25. Surface Resistance (ISO-silver): Sample #7

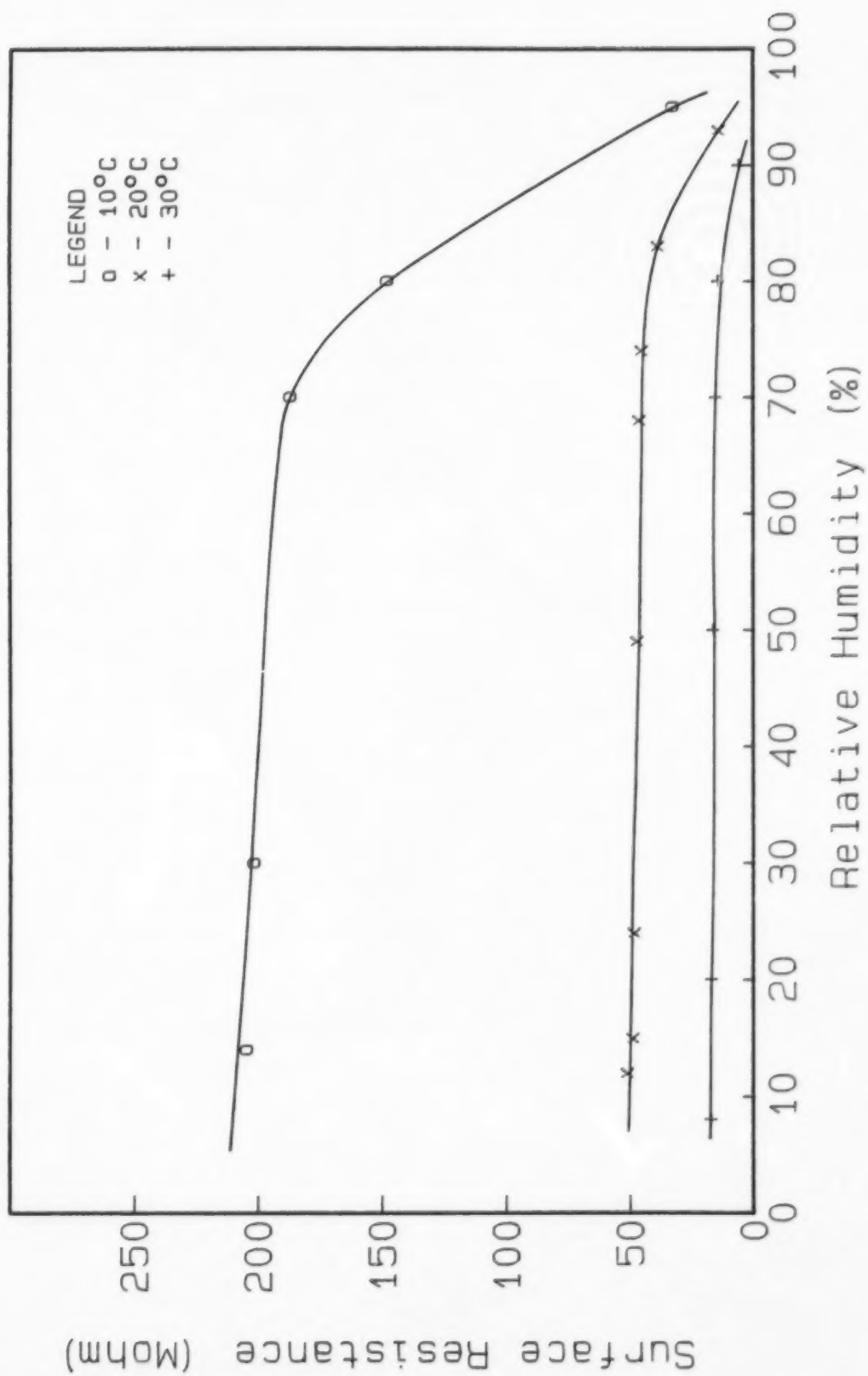


Fig. 26. Surface Resistance (CENELEC): Sample #7

